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Circular No. 710

September 1944 • Washington, D.C.

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Effects of Fire on Gum Yields of Longleaf and Slash Pines[1]

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CONTENTS

	Page
Introduction	1
Effect of surface fire	6
On longleaf pine	6
On slash pine	13
Effect of defoliation	13
On longleaf pine	14
On slash pine	17
Comparison of defoliation effects	19
Effect of steam scorching	21
Light burning	22
Heavy burning	26
Combined effect of surface fire, defoliation, and stem scorching	30
Application of results	31
Classification of fires	31
Controlled burning	32
Turpentining practice	36
Damage appraisal	37
Summary	40
Literature cited	41

INTRODUCTION

The prevention and control of forest fires in the naval stores region of the Southeast and their relation to turpentining operations have been of serious concern for many years. The war, however, has emphasized these problems by intensifying the demand for products of the naval stores woods, such as turpentine and rosin, lumber and pulpwood, and other forest items.

The shortage of manpower and equipment caused by the war has created additional problems. It is important therefore that landowners, operators, and fire-protection groups utilize all the information available for increasing the efficiency of fire prevention and control and effectively handling naval stores operations in connection with these activities.

These efforts will be aided by the information contained in this publication. The investigations described show the effect of specific phases of fire damage to naval stores values. In addition, these phases are discussed in relation to fire-damage appraisal, to turpentining of fire-injured timber, and to the use of fire in reducing inflammable fuels as a supplemental measure of fire protection.

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[1] Submitted for publication........................, ... The material presented in this circular was submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School of Arts and Sciences of Duke University.

[2] The author acknowledges with gratitude his obligation to all who have assisted in this study. He is indebted particularly to F. X. Schumacher, Paul J. Kramer, and Roy B. Thomson, of Duke University, for advice and criticism regarding the experiments and in the preparation of the report, and to J. G. Osborne, of the U. S. Forest Service, for advice and assistance in the analyses of data. He is also under special obligation to several members of the staff of the Southern Forest Experiment Station: T. E. Pease, who assisted in supervising the turpentining of the test trees and the weighing of gum, T. A. Liefeld and Frank Heyward, who helped on the experimental installations, and others who aided in the detailed field work.

The longleaf pine forests of the South have been exploited for naval stores for three centuries.[3] For the greater part of this period operators have followed the practice of raking and burning turpentine woods each winter during the normal rest period of the trees.

This procedure, known as light burning, consists of clearing away the accumulated chips, pine straw and grasses from around the tree bases, and then burning (broadcast) the ground and surface debris. The principal purpose of the annual fire was to promote a constant flow of gum in mature pines by reducing the danger of accidental burning during the later chipping season.

In an age of "inexhaustible resources," when this practice originated, little thought was given to any losses which might result from fire. Indeed, interest was centered on the protection of trees undergoing turpentining, and attention was diverted from the harm being done through broadcast burnings which prevented establishment of adequate young stands.

Only when thought was directed to the value of young pines and of fuller stands was there a realization that the custom of protecting trees through annual burning could be very costly. It began then to be evident that it was not enough to save the mature trees that were being turpentined, and that light burning, as it had been conducted, must be halted if the turpentine industry

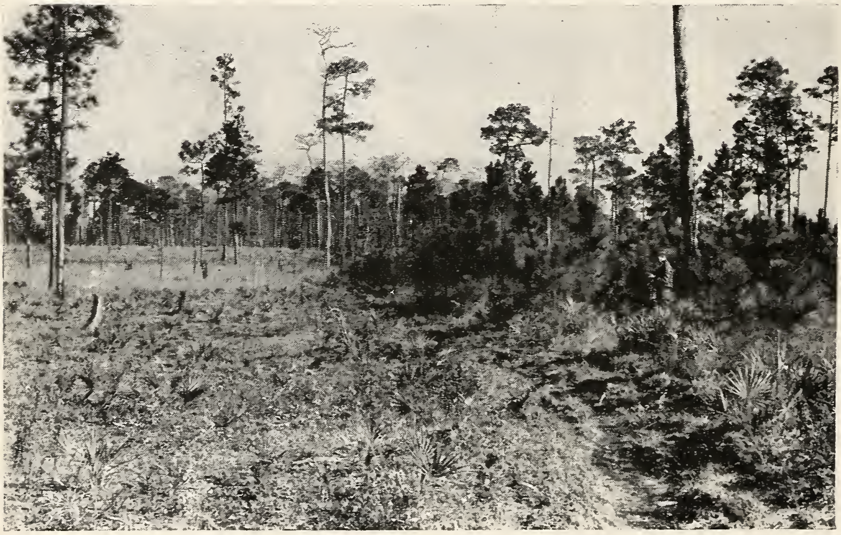

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FIGURE 1.—On the right is an excellent stand of slash pine reproduction, 8 years old, which has developed as a result of fire exclusion. On the left, as a result of the traditional method of annual burning, is the usual sparse stand of longleaf pine, with little if any reproduction.

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[3] The term naval stores here refers to the turpentine and rosin manufactured from the resin or "gum" obtained from longleaf pine *(Pinus palustris)* and slash pine *(P. caribaea).*

—which must depend upon new-growth pines for future exploitation—was to prosper.

Because the crude protective measures of earlier operators had done so much harm, the rule-of-thumb wisdom which had led these pioneers to practice light burning was lost sight of. Burning in any form became anathema, and, within the last few decades, the exclusion of fire from naval stores has been widely advocated and practiced on an increasing scale. This practice has protected the young growth and given excellent promise of fuller and more vigorous stands (fig. 1). At the same time, however, long exclusion of fire has presented some serious problems and in many situations has appeared economically impractical for several reasons.

The primary objections to prolonged fire exclusion are most convincing. Exclusion of all fires permits the development of a grassy and woody rough of high inflammability. Such areas are soon characterized by luxuriant undergrowths composed of grass, vines, shrubs, and young pines. Only a few years of fire exclusion are necessary to build up beneath the pine stands enough fuel to make possible—indeed, probable—a very serious crown fire. A fire started in this rough, under weather conditions favorable to rapid spread of fire, is almost certain to involve costly damage to the forest (fig. 2) ; and it is impracticable if not wholly impossible to maintain a fire-control system of an intensity sufficient to prevent this from happening.

In addition, the ever present risk of a damaging fire under a policy of exclusion poses for the naval stores manager several troublesome problems in the adjustment of his practice, for which forest research has thus far provided no dependable answers. When a damaging fire occurs, the consequent dead timber will mean decreased croppage, of course. Some trees, however, may be only badly scorched. Turpentining of the surviving but severely defoliated trees must be deferred for a time—but for how long? To resume turpentining too soon will result in a diminished yield and, perhaps, additional dead trees. Another baffling factor is the effect of fire on a tree's stem. If the turpentine face—the barked portion of the stem surface resulting from repeated chippings—is severely burned and the area above the face heavily scorched, the gum thereafter may cease to flow. Such wounds are rarely obvious and their extent is difficult to estimate.

Confronted by these problems, and lacking any system of insurance against losses, forest owners have of late resorted increasingly to another course of action—controlled burning, sometimes termed prescribed burning, or the planned use of fire to reduce periodically the excessively hazardous fuel volumes—and have followed this practice under conditions that cause a minimum of damage to the growth and development of pine stands.

Although practiced on an increasing scale, periodic controlled burning has varied widely in its application and the results achieved. Too many unknowns have existed, such as the various kinds of damage that may result, and the degree of control necessary to prevent undue loss. Development of adequate controlled-burning technique has been retarded by lack of a clear picture of the forest benefits and detriments of fire and of the monetary

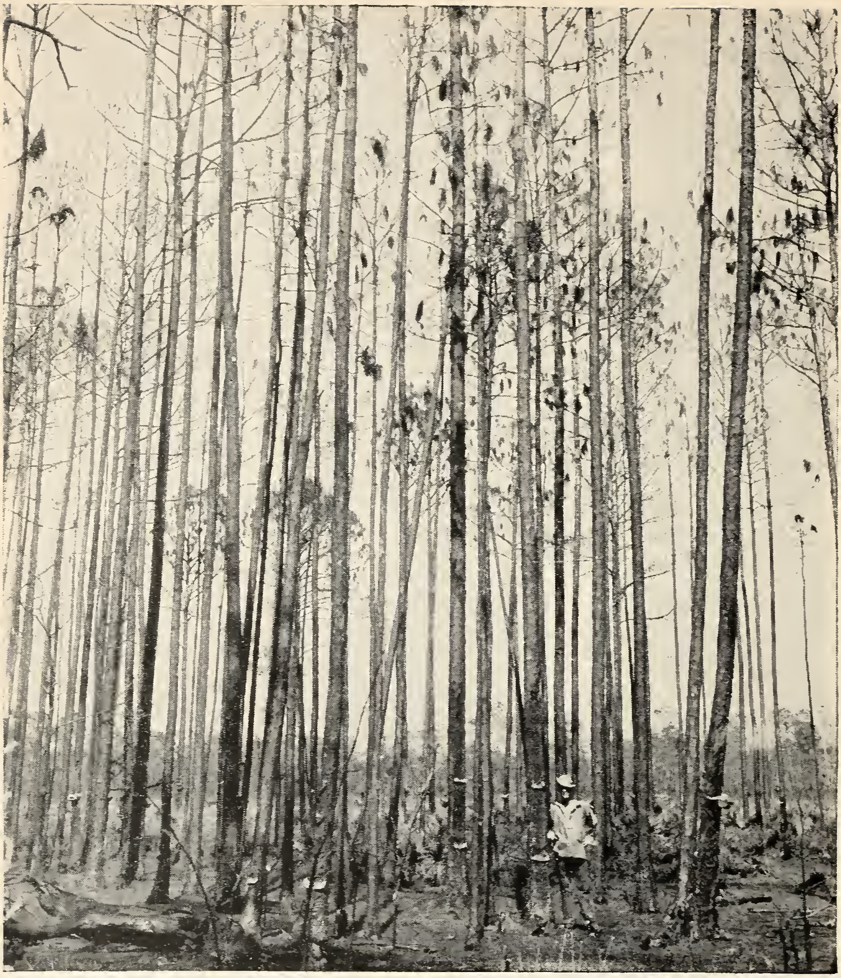

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FIGURE 2.—Turpentine pines ruined by accidental fire that swept through the rough accumulated during 10 years and more in which the stand had been protected against all fire. Within 4 months after the fire 82 percent of the trees were dead. All the others were seriously damaged.

values involved. For the most part, these questions center on fire damage and can be evaluated only through a more adequate knowledge of fire effects.

A comprehensive inquiry into the subject of fire damage to naval stores forests involves investigation of the effects of fire on the soil, on the timber and subordinate vegetation, and on gum yield. There have been many studies on the general subject of fire effects in the longleaf pine region.[4] The most complete studies have been those on the effects of fire on soil by Heyward and Barnette (*9, 10*)[5] and by Wahlenberg, et al (*18*). Several studies have dealt specifically with the effects of fire on timber, forage, and other forest vegetation (*3, 5, 7, 11, 16, 17*). A few observations or tests have been made on the effect of burning on gum yield, including those by Baker (*1*), Payne,[6] Cary (*2*), and Gerry (*6*). Little practical material, however, has been published on specific phases of fire damage to naval stores values.

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[4] U. S. FOREST SERVICE. EFFECTS OF FIRE ON FORESTS—A BIBLIOGRAPHY. 130 pp. [Mimeographed.] 1938.

[5] Italic numbers in parentheses refer to Literature Cited, p. **41.**

This circular is concerned with the class of fire effects that has received least attention thus far, namely, the effects on gum yield. Its purpose is to present the results of several experiments designed to disclose the effects on yield of various types of burning. The first three sections deal independently with the isolated effects of surface fire, defoliation, and tree-stem scorching. The fourth section considers how these separate effects can be integrated to produce a combined result. The fifth and final section brings out the application of the results to controlled burning, turpentine practice, and naval stores damage appraisal.

The field work of the study was carried out in northern Florida and southern Georgia, the area of greatest gum production (fig. 3). Most of the experiments were located on the Olustee Experimental Forest, Olustee, Fla. This forest, maintained by the Southern Forest Experiment Station, United States Forest Service, as a center for research on naval stores problems, is typical for the greater part of the naval stores region.

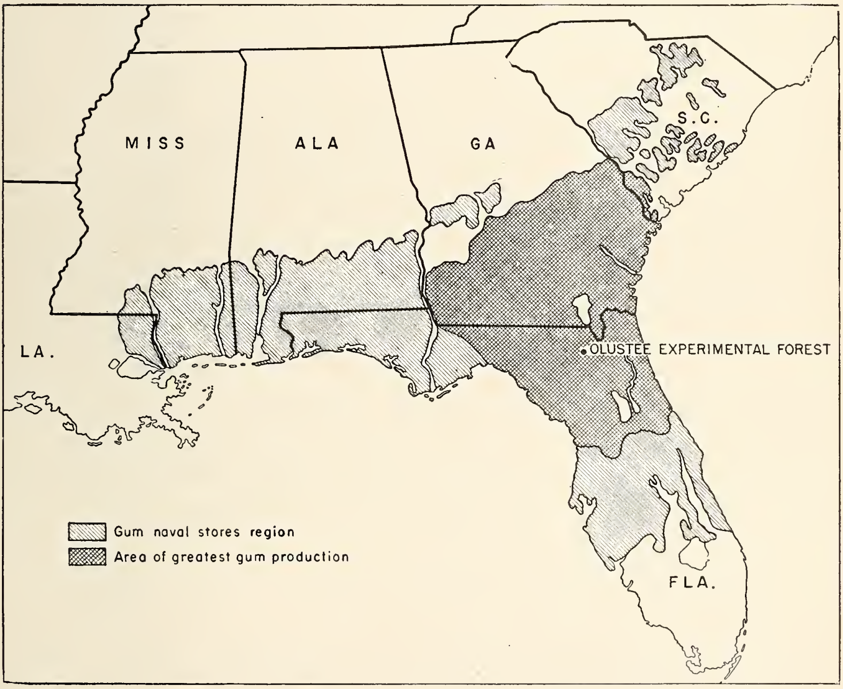
MISS
ALA
GA
S.C.
LA.
FLA.
OLUSTEE EXPERIMENTAL FOREST
▨ Gum naval stores region
▩ Area of greatest gum production

FIGURE 3.—The naval stores region, showing area of greatest gum production and location of study area.

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[6] PAYNE, H. M. THE NAVAL STORES SITUATION IN THE UNITED STATES. U. S. Dept. Com. 38 pp. [Mimeographed.] 1932.

EFFECT OF SURFACE FIRE

As has been indicated, experiments were first directed toward ascertainment of the effects of the surface fire as such, isolated from any effects upon either foliage or tree stem. These tests, under what were manifestly somewhat artificial conditions, simulated the carefully controlled surface fire and supplied data upon an important phase of the typical light burn. The tests were concerned primarily with longleaf pines but consideration was also given to slash pines.

ON LONGLEAF PINE

The experiment to determine the effect of surface fire on gum yield was established in a second-growth stand of longleaf pine that, following a number of light annual burnings, had been protected from fire for 2 years.

The experiment was carried out on two adjoining 3½-acre plots, on each of which 178 trees ranging from 8 to 12 inches d.b.h. (diameter at breast height, or 4½ feet above the ground) were selected for study. The experiment, begun in 1933, extended over a 5-year period. During the first year neither of the plots was burned over, but the test trees were turpentined. In the second and in the third year plot B was burned over prior to the start of turpentining, while plot A remained unburned. In the fourth year the burning treatments were continued on plot B as before but none of the trees was turpentined. In the fifth year the fire treatments were reversed—plot A was burned and plot B was not—and the test trees again were turpentined. The purpose of the reversal in the last year was to eliminate the possibility of correlation of burning treatment with plot location.

TABLE 1. *Effect of surface fire on gum yield of longleaf pine*

Year and treatment	Age of ground cover on plot A	Unadjusted average yield per tree [1]				Adjusted difference ascribable to burning [2]	
		Plot A	Plot B	Difference			
	Years	*Ounces*	*Ounces*	*Ounces*	*Percent*	*Ounces*	*Percent*
1933: Both plots unburned	2	102.708	103.670	0.962	0.9	0.143	+0.1
1934: Plot A unburned, B burned	3	111.826	117.335	5.509	4.9	4.480	+4.0
1935: Plot A unburned, B burned	4	94.956	100.026	5.070	5.3	4.005	+4.2
1937: Plot B unburned, A burned	....	93.197	91.722	1.475	1.6	....	+2.7

[1] Based on 178 trees per plot.

[2] The odds are at least 100 to 1 that all differences as large as those shown, except for 1933, are not due to chance.

All surface-fire treatments were applied during the winter, usually in January. Just prior to burning, all inflammable material such as chips, pine needles, and grasses were raked from around the bases of the test trees, including those on the plot not to be burned, and during burning particular care was taken to keep fire from scorching the foliage. Chipping was begun in March and was continued at weekly intervals for 32 weeks. At intervals of 4 weeks the gum from each tree was collected and weighed to the nearest ounce. The averages, by fire treatment, and the statistical significance of the difference between plots are given in table 1.

Magnitude of the Effect.—In analyzing the yields to determine the effect of the surface fire, various methods were used, depending upon the refinement of statistical control needed. In general, except for the final year of the experiment, the method was first to determine for the trees on the unburned plot the relation of gum yield to certain tree characteristics by linear, least-squares regression, and then to apply the equation thus obtained to the data for the trees of the burned plot. Since the latter operation furnished an estimate of the yield that was to have been expected from the trees of the burned plot had the plot not been burned, the difference attributable to surface fire was found by simply comparing the sum of the yields thus estimated with the sum of the measured yields. For the preliminary year 1933, in which fire was not applied to either of the two plots, the tree characteristics used in the multiple regression were diameter and growth rate, and the analysis showed a difference in yield between the two sets of trees of only 0.1 percent. This small difference, in contrast to one of 0.9 percent obtained by direct comparison, indicates the added refinement in experimental control that was accomplished by the regression analysis. For the 2-year period 1934-35, the tree characteristics used in the regression equation were the same as those for 1933 plus one other factor—initial yield capacity of trees—in 1933.[7]

For the final year of the experiment, 1937, the method of determining the difference in yield due to surface fire was: First to add the uncorrected differences in yield between the two sets of trees obtained for 1935 and 1937; and, second, to compare their sum with the corrected difference obtained for 1935. This simplified procedure was made possible by the fact that fire treatments on the two plots had been reversed in 1937.

Each year in which fire was applied and yields were measured the trees on the burned-over plot produced more gum than those on the unburned plot. For 1934 and 1935 the adjusted differences due to surface fire were approximately 4 percent. For 1937, the season when fire treatments were reversed, the difference was still significant.

Nature of the Effect.—The experimental evidence presented offers convincing proof that burning of ground cover does not have a deleterious effect but rather a beneficial effect on gum yield. The increases in yield as a result of the fires were not large, but they were prompt, consistent, and statistically significant.

Although the nature of the effect of burning ground cover on

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[7] Thus the equation developed for the 1935 unburned plot was

$$Y = -0.2608X_1 - 1.5114X_2 + 1.3288X_3 + 20.3220.$$

in which, for any given tree, Y = deviation in ounces of 1935 yield from yield of 1933, X_1 = 1933 yield in ounces, X_2 = number of growth rings in the last radial inch (at breast height), and X_3 = diameter, in inches, 4½ feet above ground. The dependent variable Y was expressed in the above form because of the closer control of experimental error thus provided. (Before the fire-treatment effects were compared finally, Y was converted of course to direct readings of 1935 estimated yields.) Because of the effects of the independent variables on yield, and hence the importance of considering them in experiments such as this, it should be noted (1) that the yield of the original high yielders declined faster than that of the medium-to-low yielders; (2) that the yield of the slow-growing trees declined more than that of the fast-growing trees; and (3) that the larger trees maintained their original yield level better than did the smaller trees.

gum yield was not studied directly, it is possible, with the aid of results of previous studies, supplemented to a considerable extent by observations during the course of the present experiment, to suggest two explanations for the increased yield. One possible explanation is the improved soil fertility brought about by the fire; the other is the higher soil temperature of the burned plot in comparison with the unburned.

According to the soil-fertility hypothesis, the connection between surface fire and increased yield is briefly that: (1) fire creates a favorable chemical composition of the soil; (2) this in turn results in increased food manufacture by the tree; and (3) the resulting increase in growth is responsible for the increased gum yield. If the first two processes actually took place, there is little doubt about the third; abundant evidence furnished by naval stores research and experience shows that gum yield is positively correlated with growth rate.

The best evidence of a favorable chemical reaction in the soil is provided by the recent fire and soils work of Heyward and Barnette (*9*) in the longleaf pine region, in which they found more total nitrogen and a greater quantity of replaceable calcium in burned-over soils than in soils not burned-over. These investigators regard the roots of grass as the main source of appreciable amounts of organic matter in soils that are frequently burned over. Also, since the higher replaceable calcium content of the soils may be attributed to the addition of ash following fire, they assume that the quantities of potassium, magnesium, phosphorus, and other constituents of ash are probably likewise somewhat increased by fire.

The effect of such soil changes on food manufacture and growth of mature pine trees has never been studied, so far as is known. It is conceivable that they could increase growth and other physiological activities of mature turpentine trees. But whether such changes would cause an immediate response in gum yield seems somewhat doubtful.

The assumption that improved soil fertility resulting from burning is the primary reason for increased gum yield, presents some interesting implications regarding the effectiveness of the various soil changes. The indications are that the increase in yield would be due indirectly to a gradual change in nitrogen mobilization in the soil, facilitated by the base elements deposited in the ash, rather than directly and immediately to the tree's absorption of increased ash constituents. This follows from comparison of fire histories of the plots, along with comparison of yields. The margin between burned- and unburned-plot yields widened slightly over the two years 1934 and 1935. Moreover, after fire treatments were reversed, the least difference of all was obtained—this in spite of the fact that the burned plot in this instance had the longest protection history, the greatest accumulation of litter, and consequently the greatest deposit of ash.

The second possible explanation of the relation of surface fire to increased gum yield, namely, that the increase is due to a higher soil temperature, is the better supported of the two theories, even though some of the links in the connecting chain of processes are either unknown or imperfectly understood. This explanation assumes that: (1) Removal by fire of the insulating cover of dead vegetation caused an increase in soil temperature; (2) this sets certain physiological processes into motion that lead immediately to an increased gum yield. It is possible, for example, that an increase in soil temperature tends to increase a pine tree's ability to absorb water. Kramer (*11*) found an 18-percent reduction in water intake of slash and loblolly pines when the soil was cooled from 25° to 20° C. Should an increased absorption of water take place, it is further possible that a favorable effect on gum yield comes about through more favorable cell hydration, since it has been noted by Harper and Wyman (*8*) that the gum flow of slash pines decreases during the day with reduction in water content of the trees.

That soil temperature was actually higher on the burned plot of the present study area was determined in 1936, and again in 1937. In 1936, from July 17 to August 12, soil temperature at two depths was measured at a single location on each plot three times a day. The average daily temperatures were as follows:

	°*F.*
1½-inch depth:	
Burned plot	85.6
Unburned plot	83.7
Difference	1.9
4½-inch depth:	
Burned plot	82.5
Unburned plot	81.0
Difference	1.5

In 1937, temperatures at these same depths were again determined. The measurements were taken three times a day on three days a week for the period March to December, corresponding approximately to a turpentining season. Thermometers were installed at five locations, chosen at random on each plot. The averages by soil depth and for the three readings per day (9 a.m., 1 p.m., and 4 p.m.) are given in figure 4. For each depth and time of day the soil temperature on the burned plot was higher for most of the season, the maximum difference occurring about June. The average differences were somewhat less in 1937 than in 1936. This undoubtedly is due to the differences in insulation of the protected plots. In 1936 the comparison was between a 5-year ground cover and a winter burn; whereas in 1937 it was between a 1-year ground cover and a winter burn.

The theory that an increase in soil temperature is instrumental in causing an increase in yield is supported by Harper and Wyman's (*8*) study of the effect of weather factors on gum yield, and by data of the present study. Harper and Wyman found that a 1-degree rise in the factor soil-minus-air temperature resulted in a gum-yield increase of about 2 percent, and that a 1-degree rise in air temperature resulted in a yield increase of about 4 percent.[8] Although the soil temperature readings were taken at an

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[8] The net relation of soil-minus-air temperature to yield was approximately linear so long as soil temperature did not exceed air temperature by more than about 10° F., which it rarely did. Also, the net relation of air temperature to yield was approximately linear over all but the upper and lower extremities of the temperature range.

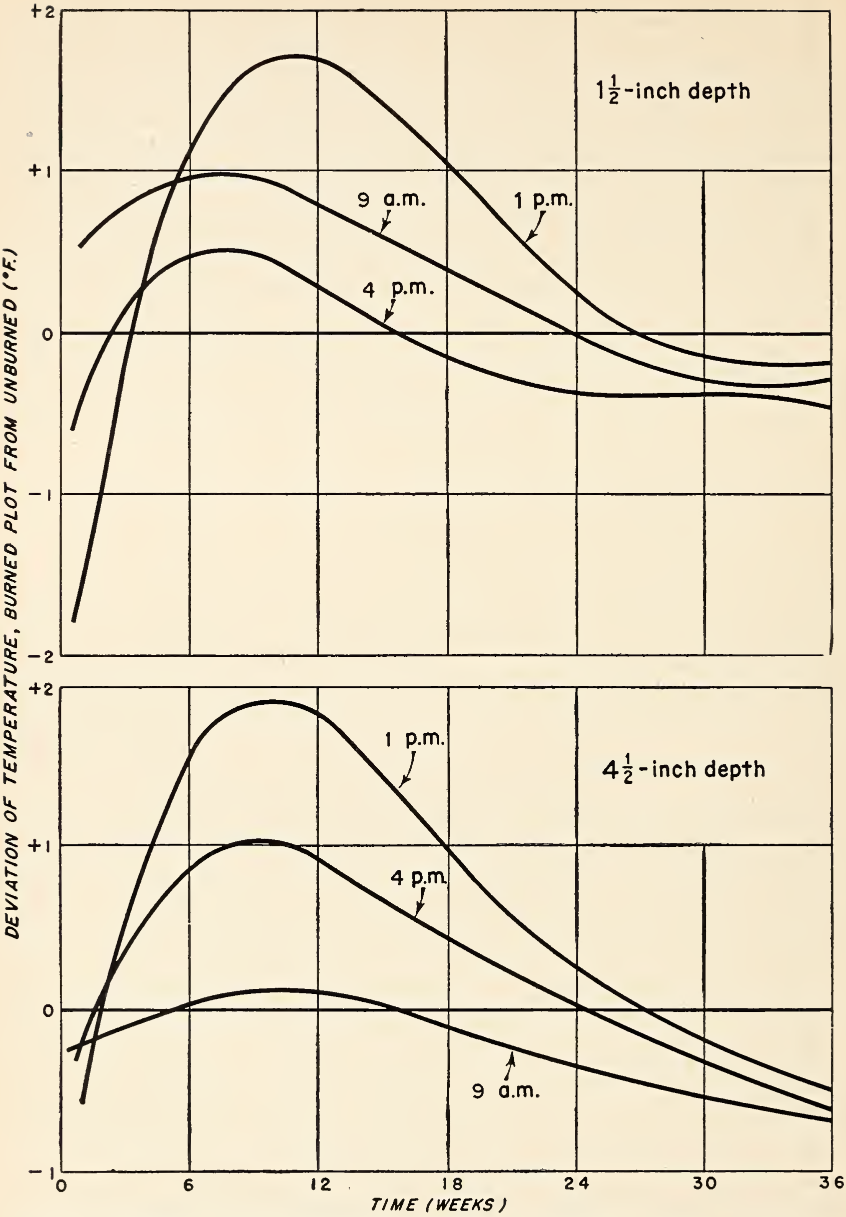
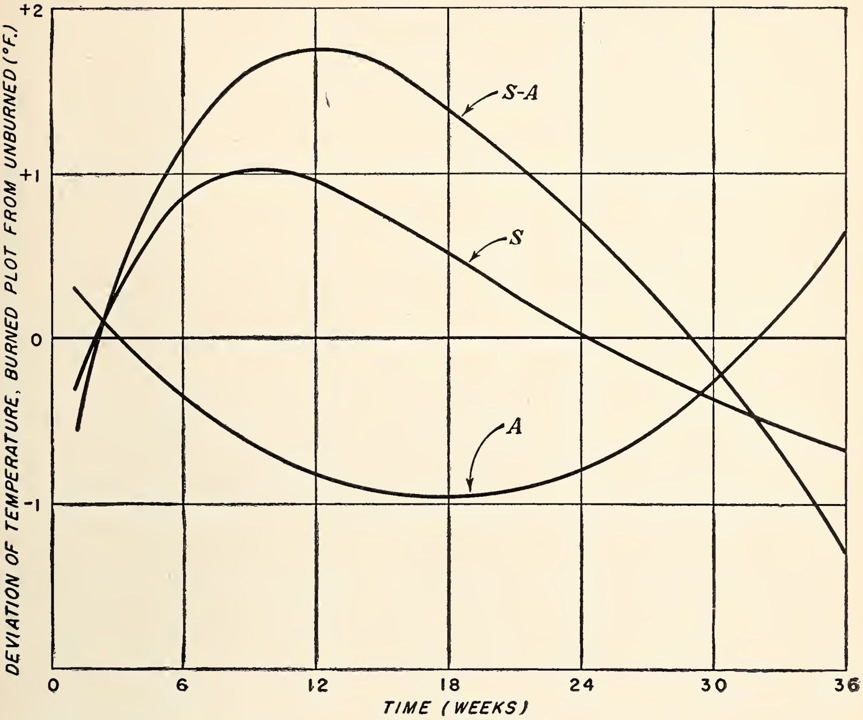


FIGURE 4.—Effect on soil temperature (March to December, 1937) of burning of soil cover by surface fire.

18-inch depth and the net effect of soil temperature as a separate factor was not determined, it is possible to express the above results in terms of approximate influence of soil temperature at shallower depths, such as those of the present study. Thus, it is reasonable to assume that had soil temperature readings been taken at a 4½-inch depth, a 1-degree change in the factor soil-minus-air temperature would have represented a greater net effect on yield, since soil temperatures may be expected to respond to changes in air temperature with less lag at 4½ inches than at 18 inches. Accordingly, for soil temperatures at a 4½-inch depth, it appears probable from the study of Harper and Wyman's data that a 1-degree rise in the factor soil-minus-air temperature would have associated with it an increase in gum yield of about 4 percent, or an amount equal to that correlated with a 1-degree rise in air temperature.

In addition to the difference in soil temperature between the burned and unburned plots, a difference was also found in air temperature. Air temperature was higher on the unburned plot (fig. 5). This means that two counteracting temperature influences were operating on the burned plot, one to increase yield and the other to decrease it. On the assumption, however, that for each 1-degree change the effect of the soil-minus-air temperature equals that of the air temperature, it can be demonstrated algebraically that air temperature cancels out, leaving only the effect of the difference in soil temperature to be reckoned with. By letting S = the effect of soil temperature, A = the effect of air temperature, b = burned plot, and u = unburned plot, the equation is developed,



IGURE 5.—Soil and air temperature differences (March to December, 1937) between burned and unburned plots: *S*, Average daytime soil temperature at 4½-inch depth; *A*, average daytime air temperature at 3 feet above ground; *S-A*, soil temperature minus air temperature.

$$(S_b - A_b) - (S_u - A_u) + (A_b - A_u) = S_b - S_u.$$

According to the probability that a rise of 1 degree in soil temperature causes a 4-percent increase in gum yield, a rise of 0.8 degree would cause a 3.2 percent increase. In 1937, the average difference between the two plots in soil temperature was 0.8 degree; in gum yield it was 2.7 percent. Hence the difference in soil temperature is large enough to have accounted for the increased yield.

The experimental data collected in this study, moreover, show that there is a close relationship not only between soil temperature and gum yield (fig. 6) but also between age of ground cover and gum yield (table 1). The amount of ground cover, of course, increased with time elapsed since burning, and the greatest difference in ground cover for the two plots was accompanied by the greatest difference in gum yield.

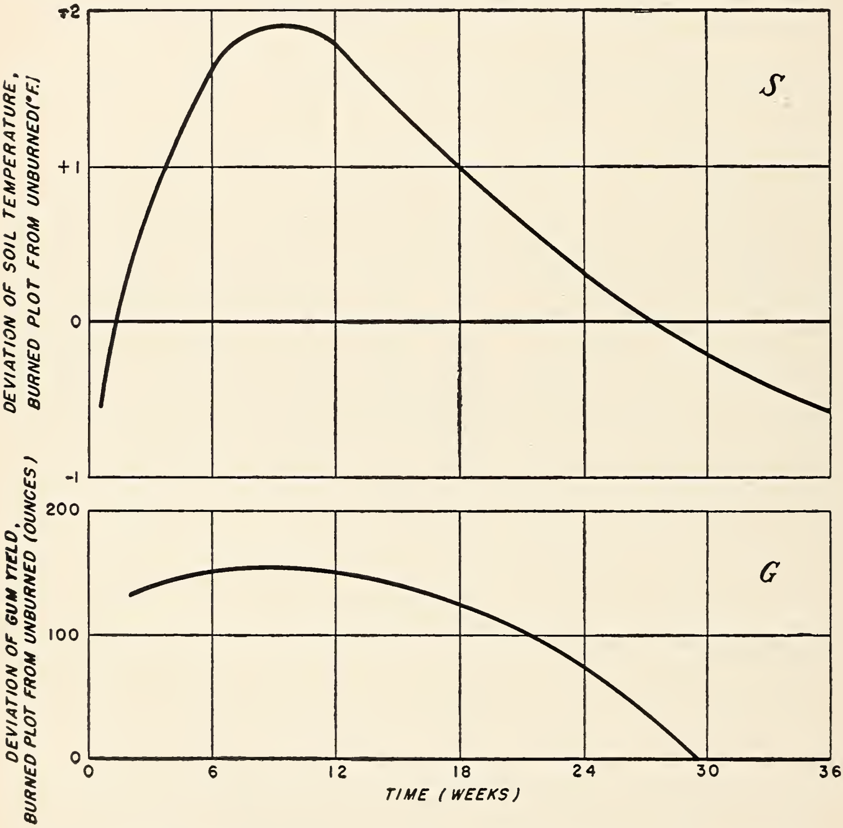


FIGURE 6.—Trends in the differences of soil temperature and longleaf pine gum yield caused by burning of ground cover: *S*, difference in soil temperature at 1 p.m., between burned and unburned plot at the 4½-inch depth (during 1937); *G*, average difference (in 1934-35) in total gum yield, between burned and unburned plot.

As shown in figure 6 the greatest difference in either gum yield or soil temperature occurred near the beginning of the turpentining season (in June) and the least difference at the end of the turpentining season. The downward trend is attributed partly to accumulation of new ground cover on the burned plot as the season advanced and partly to change in directness of the sun's rays. Apparently the yield variation between plots is due primarily to variation in insulating effect of the ground cover.

In brief, present evidence gives some support to both hypotheses regarding the influence of surface fire on the gum yield of longleaf pine—soil-fertility and soil-temperature—but of the two it indicates that the soil-temperature explanation is the more probable. Further research may show that both types of reaction are involved. If the soil-temperature explanation is accepted, obviously an increase in yield will be expected during the first season after surface fire only when a reasonably heavy insulating soil cover has been removed. Under protection from fire, most areas throughout the naval stores region have heavy insulating covers of one kind or another (fig. 7). Some areas, however, because of inadequate soil moisture or other cause, do not support heavy soil covers. Accordingly, the change in yield to be expected during the first year following surface fire will undoubtedly vary among sites, from little or no increase on some to a probable maximum increase of around 6 percent on others.

ON SLASH PINE

The results of the surface fire experiment can fairly be extended to include slash pine. Changes in soil temperature or soil fertility are changes in a tree's environment. Such changes in environment due to burning must necessarily be the same for both species, since the ground covers associated with the two species are similar in character. Therefore, whether the effect of surface fire on yield would be the same for slash pine as for longleaf pine really narrows down to a question of the manner in which yields of the two species respond to changes in conditions of environment.

Several studies have indicated that the yields of the two species react alike to environmental conditions. Harper and Wyman (*8*) found this to be true for many weather factors, including soil temperature in particular. Apparently this is true also for soil fertility, since growth rate, an expression of soil fertility, has been observed to influence the yield of both species in the same manner. Undoubtedly, therefore, the increase in yield following a surface fire that was observed for longleaf pine can be expected also for slash pine. As indicated in table 1, and the preceding discussion, this increase is probably about 4 percent, the precise amount being dependent upon the character and depth of ground cover burned.

EFFECT OF DEFOLIATION

A turpentine tree may be defoliated by fire in one of two ways: By heat killing from a surface fire, which causes a gradual falling of needles; or by the immediate destruction of foliage, as occurs in a crown fire. If defoliation is caused by a surface fire, the crown may be completely denuded or only a part of the foliage may be killed, depending upon local burning conditions such as ground fuel and wind. Defoliation caused by a crown fire is always very extensive and is usually accompanied by some injury to buds

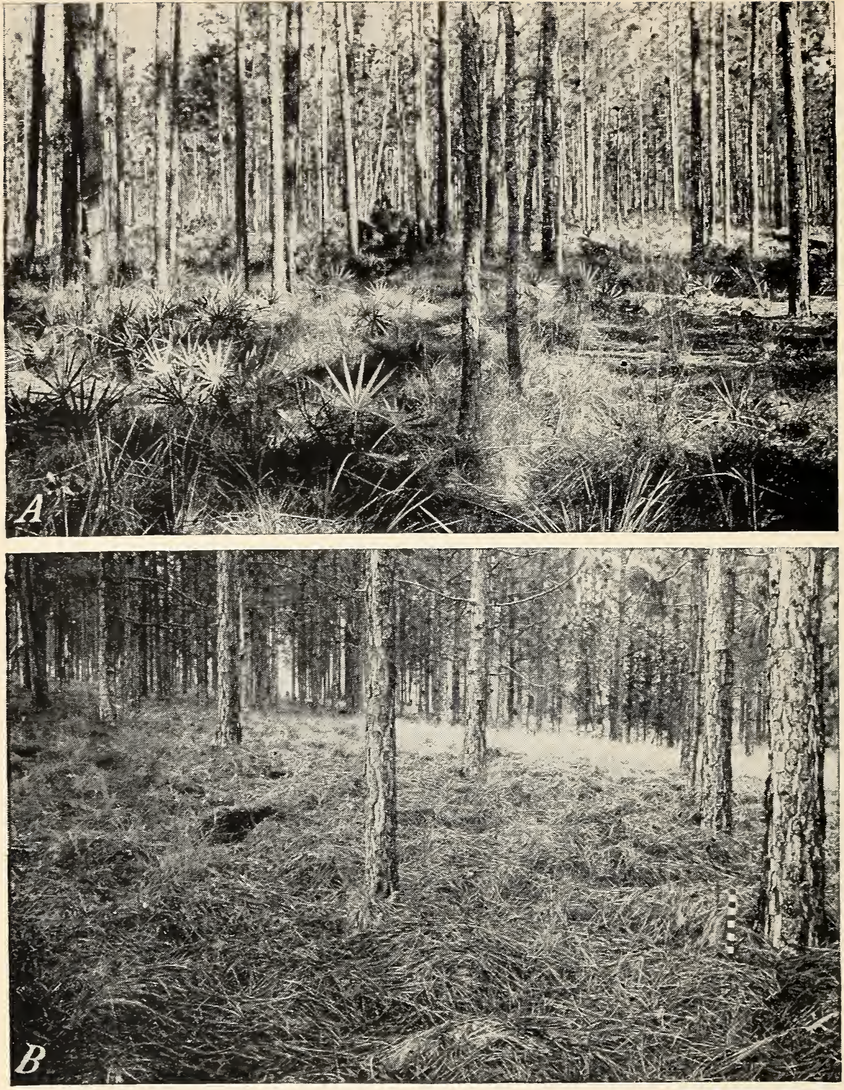


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FIGURE 7.—Exclusion of fire produces a heavy insulation of undergrowth or leaf litter. (*A*), Four-year rough on the Olustee Experimental Forest, typical for longleaf pine forests of the Georgia and Florida flatwoods. (*B*), Heavy soil cover of pine needles under a closed stand of longleaf pine, near Adrian, Ga., long protected from fire.

and twigs. Needle loss to either slash pine or longleaf pine as a result of accidental fire may occur at any season of the year. In the present study of the effect of defoliation on gum yield, consideration was given to the manner, extent, and season of needle loss and to possible differences in effect between species.

ON LONGLEAF PINE

The effect of heavy and light defoliation on the gum yield of longleaf pine has been partially explored by Cary (*2*) and Gerry

(*6*). These investigators, in studying the results of an autumn fire in a longleaf pine stand, observed that of one group of trees thoroughly scorched by the fire about half either were killed outright or ceased to exude gum shortly after the beginning of turpentining in the following spring. All the survivors showed a markedly reduced yield during the first succeeding year of turpentining but recovered sufficiently by the end of the second year to yield at approximately normal rates. In contrast, a group of trees slightly defoliated in the same fire showed very little if any reduction in yield.

These observations clearly indicate that it is wise to defer turpentining after a severe crown fire. Deferment for at least 2 years will prevent markedly reduced yields after a bad fire and eliminate the possibility of promoting tree or face mortality. In general, this practice is followed by naval stores men. The observations indicate also that a 2-year deferment, discussed below, should be sufficient.

To explore further the effect of flame and heat defoliation on yield of longleaf pine two experiments were performed. In the first, the treatments consisted of direct applications of flame for the purpose of causing injuries corresponding closely, as far as could be judged, to damage by light to medium crown fire. In the second, a single treatment was applied in a manner to simulate heat defoliation caused by a severe surface fire.

In establishing the experiments, 88 trees were selected on the basis of uniformity of size from a uniform, well-stocked stand of second growth approximately 35 years old. In February 1933, before any fire treatments were applied, the trees were given three turpentine chippings, 7 days apart, to determine their relative yield levels. Immediately after this, the trees were arranged into four equal-yielding groups. Each group contained 22 trees, of which 2 were extras, to replace any which might be killed by fire or by other agencies.

Flame defoliation treatments were applied in March 1933. Three years later, in June 1936, the heat defoliation treatment was applied. The former consisted in burning off the needles with a torch made of ordinary oiler's waste that had been soaked in kerosene. The latter consisted in killing the needles by holding a lighted torch so that flame was close to, but not in contact with the foliage. Flame defoliation took one-third of the crown in group 2, two-thirds in group 3, and the whole crown in group 4. Heat defoliation, applied to the trees in group 2, took two-thirds of the crown.

Turpentining of the flame-defoliated trees continued for two seasons after treatment; that is, from March to November 1933 and in 1934. The heat-defoliated trees were turpentined during 1935 and in 1936, although the heat-defoliation treatment was not applied in 1936 until June. All trees were chipped at exactly 7-day intervals and the yields resulting from each chipping were weighed to the nearest gram. The deviations in average yields between different groups of flame-defoliated trees in the years 1933 and 1934 are shown in figure 8. Figure 9 shows the difference in yield of gum from trees given no heat treatment in 1935 as compared with trees given heat-defoliation treatment in 1936.

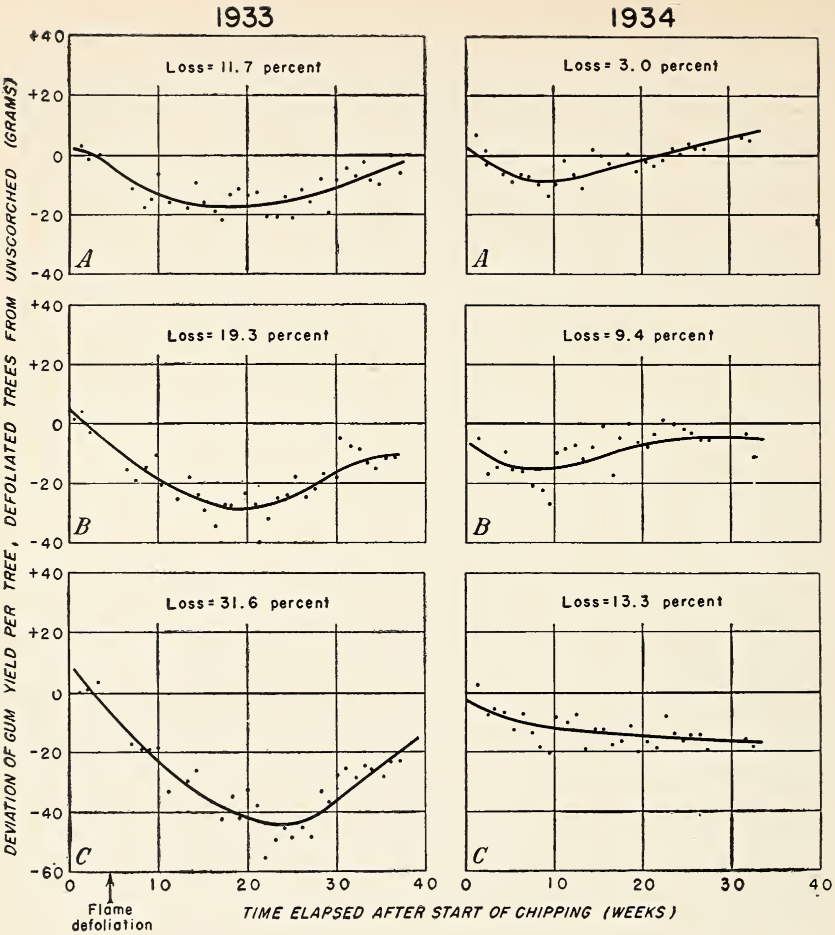

FIGURE 8.—Effect of defoliation by flame in March 1933 on gum yield of longleaf pine in 1933 and 1934: *A*, Crowns one-third defoliated; *B*, crowns two-thirds defoliated; *C*, crowns completely defoliated. (In each year, regular chipping began in March; in 1933, three preliminary streaks were put on in February as a basis for matching groups.)

Defoliation of trees by flame resulted in considerable reduction of gum yield (fig. 8). For the first season after fire the average losses were 11.7, 19.3, and 31.6 percent, respectively, for the trees of the 1/3-, 2/3-, and 3/3-defoliated groups. For the second season they were, in the same order, 3.0, 9.4, and 13.3 percent. The lowest point in yield of each fire-treated group occurred during midseason of the first year. In general, as revealed by the trend curves, the yields of all groups were practically back to normal by the end of the first year. This rapid recovery in yield is attributed to the prompt development and growth of new foliage during the first season after the fire. The fact that the two-thirds and three-thirds groups averaged somewhat less than the check group for the second year is not regarded seriously, since the matching of the groups to be defoliated and the check

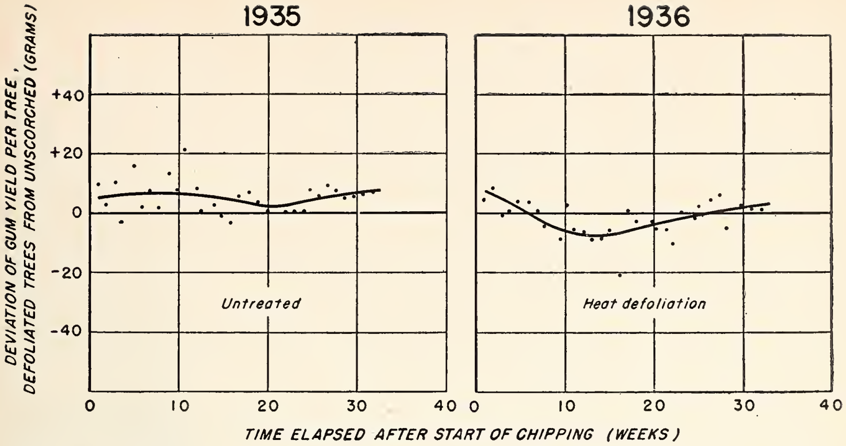

FIGURE 9.—Effect on longleaf pine gum yield of heat-defoliation treatment in June 1936 that caused two-thirds defoliation of the crowns. The deviations in yield for 1935 from trees given no heat treatment, as shown, form the basis for estimating decreased yield due to treatment in 1936. (Chipping began in March of each year.)

groups was based on yields during a preliminary period of only 3 weeks.

In sharp contrast to flame defoliation, heat defoliation caused considerably less reduction in yield (fig. 9). Moreover, the reduction persisted over a very short period only. The loss was computed to be 8.5 percent, made up of a 7.0 percent excess yield of group 2 over group 1 (check group) for the year prior to treatment; and a 1.5 percent deficiency in yield of group 2 as compared with group 1, for the year in which the fire treatment was applied. The 8.5-percent loss in yield, caused by heat defoliation in June, is slightly less than half the reduction caused by flame defoliation of equal extent in March.

ON SLASH PINE

A group of 65 young slash pines ranging from 8 to 12 inches in diameter at breast height was used in the study of effects of fire defoliation on gum yield of slash pine. In 1936, a year prior to the first treatments, these trees were turpentined and their yields carefully measured.

Heat defoliation treatments applied in March 1937 consisted in subjecting the trees to various degrees of scorching that caused defoliation ranging from 5 to 100 percent in each size group. Regular weekly chipping began in March, immediately after defoliation, and continued until November.

The yields were analyzed by least-squares regression in which defoliation, air temperature, and time since initiation of chipping were the independent variables. The equation developed from the data was

$$Y = 273.785 + 3.100X_1 + 1.310X_2 - 0.126X_3,$$

in which Y is the deviation of a tree's yield for a particular week from its average yield in 1936,[9] X_1 is the maximum air temperature (°F.) on the first day of each weekly streak, X_2 is the number of weeks elapsing after initiation of chipping for the season, and X_3 is the defoliation by heat in percent of total crown area.

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[9] The dependent variable, yield, was expressed in this form rather than simply as yield of 1937 to gain as much sensitivity as possible in order better to define the influence of the defoliation variable.

In this analysis interest centered on the partial regression of yield on defoliation, with the effects of temperature and time elapsing after initiation of chipping largely removed. For each 10-percent increase in defoliation, the yield for the turpentining season was reduced on the average by 1.26 grams per week. Since the average yield of the most lightly scorched trees was about 148 grams per week, this reduction for each 10-percent increase in defoliation amounts to approximately 0.85 percent. Thus 1/3 defoliation reduced yield by 2.8 percent; 2/3 defoliation, by 5.7 percent; and complete defoliation, by 8.5 percent. Inspection of weekly yields revealed that by the end of the 1937 season the gum flow for all trees was normal.

A second experiment on these slash pine trees included determinations of the effects of both heat and flame defoliation. A total of 64 trees was divided into 8 groups of 8 trees each, to each of which one of the following treatments was assigned at random:

Heat defoliation	*Flame defoliation*
1/3 crown	1/3 crown
2/3 crown	2/3 crown
3/3 crown	3/3 crown
None	None

Treatments were applied in May 1938. Gum yields were measured after each chipping by weighing the gum (1) after the first 24 hours and (2) at the end of each 7-day period.

Separate analyses of the data were made for first-day yields and 7-day yields. The type of analysis was the same in each case. Essentially, the method was to provide, on the basis of check-tree yields, an estimate of what the yield of each tree for each streak would have been in the absence of treatment. The estimated yields were then compared with the actual yields for each streak, and the difference was attributed to the fire treatment.[10] The average deviations of the yields of the treated groups from those of the untreated groups, and their statistical significance, are given in table 2, and yield trends are given in figure 10. Complete defoliation by heat reduced yield by 19.2 percent. The reduction in yield of the flame-defoliated trees was much greater, complete defoliation resulting in 63.6 percent loss in yield.

By the end of the turpentining season all trees that had been defoliated, whether by flame or by heat, had recovered to the extent that they were yielding at a normal rate or a rate approaching normal (fig. 10). In this respect the reaction of slash pine yields to crown scorching is similar to that found for longleaf pine.

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[10] The equation developed was of the form $Y_{kj} = Y_{cj} + b_j Y_{k'}$, in which Y_{kj} is the yield of any treated tree k for a particular week j, Y_{cj} is the average yield of the trees in the check group for week j, and b_j is a regression coefficient obtained by correlating the yield deviation for each check tree from the average for all check trees with the average 1936 weekly yield of that same tree; and $Y_{k'}$ is the average 1936 yield of tree k. Because 16 trees provided only a rather weak basis for the regression coefficient b_j and it was felt that the regression coefficient was controlled to some extent by the yield level, b_j was replaced in the equation by the expression $a + dy_{cj}$. The latter was obtained by correlating the previously computed b values for each streak with the average yield of the check trees for that week. Thus the final equation which was used for estimating normal yields of the treated trees was

$$Y_{kj} = Y_{cj} + (a + dy_{cj})\ Y_{k'}.$$

TABLE 2.—*Effect of defoliation by fire on gum yield of slash pine, in terms of deviation from normal yield*[1]

Kind and degree (portion of crown) of defoliation	1-day gum flow—average deviation from normal and statistical significance			7-day gum flow—average deviation from normal and statistical significance		
	Grams	*Percent*	*Statistical significance*	*Grams*	*Percent*	*Statistical significance*
Heat:						
1/3	−8.1	−2.3	None	−14.8	−1.5	None
2/3	−24.5	−5.7	High	−128.1	−11.9	High
3/3	−40.6	−11.2	do.	−190.9	−19.2	do.
Flame:						
1/3	−33.2	−7.9	do.	−79.4	−7.4	do.
2/3	−129.9	−28.0	do.	−392.4	−34.5	do.
3/3	−290.1	−53.4	do.	−780.5	−63.6	do.

[1] Deviations are in terms of total yield of 8 trees; normal yield is the average for the two unscorched groups of 8 trees each. The results are for the portion (26 streaks) of the season of 1938 remaining after the fire, which was applied in May.

The greater retardation of gum flow following flame defoliation is attributed primarily to the injury of bud and stem tissues at the time the foliage was burned, an effect absent or negligible in heat defoliation. Support for this explanation lies in the fact that, in comparison with the heat treatments, the flame treatments caused relatively greater retardation of gum flow for the first day than for the 7-day period (table 2). The relatively light loss in gum flow from heat-defoliated trees on the first day suggests that depletion of the food supply was the sole cause of loss. Although gum formation was maintained fairly well during the first day, it subsided at an accelerated rate as available raw materials in the cells affected by the chipping became exhausted. This is a normal reaction to needle loss alone. In the flame-defoliated trees, the relatively heavy loss in yield on the first day of gum flow suggests the influence rather of some factor that affected gum formation than supply of raw material. Apparently this factor is a toxic substance, originating in the cells of the stems and buds as a direct result of their injury by fire. The release of this substance into the transpiration stream of the tree evidently has an inhibiting effect on gum formation, causing an immediate limitation of gum flow.[11] On the other hand, raw materials not actually utilized on the first day would be available for subsequent days; consequently, even though the toxic substances continued to be in force, gum formation could proceed at a fairly uniform rate.[12]

COMPARISON OF DEFOLIATION EFFECTS

The results of the defoliation experiments described are summarized in table 3 and in figure 11. To facilitate direct comparison

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[11] Dixon (*4*) has shown that poisonous substances from heat-injured cells are quite deleterious to cell activity.

[12] Other possible causes of the decrease in yield from trees with fire-injured buds are: (1) Diversion of raw materials to products other than resin, in which an increase in respiration known to follow injuries to tissues (*13*) is one of the processes; and (2) a modification of hormone action following damage to buds. The former may conceivably result in sufficient drain on the supply of raw materials to interfere with gum formation. Little is known about the latter, but a hormone from the tree's crown may be involved in controlling the rate of gum synthesis, and destruction of some of the buds possibly upsets the normal influence.

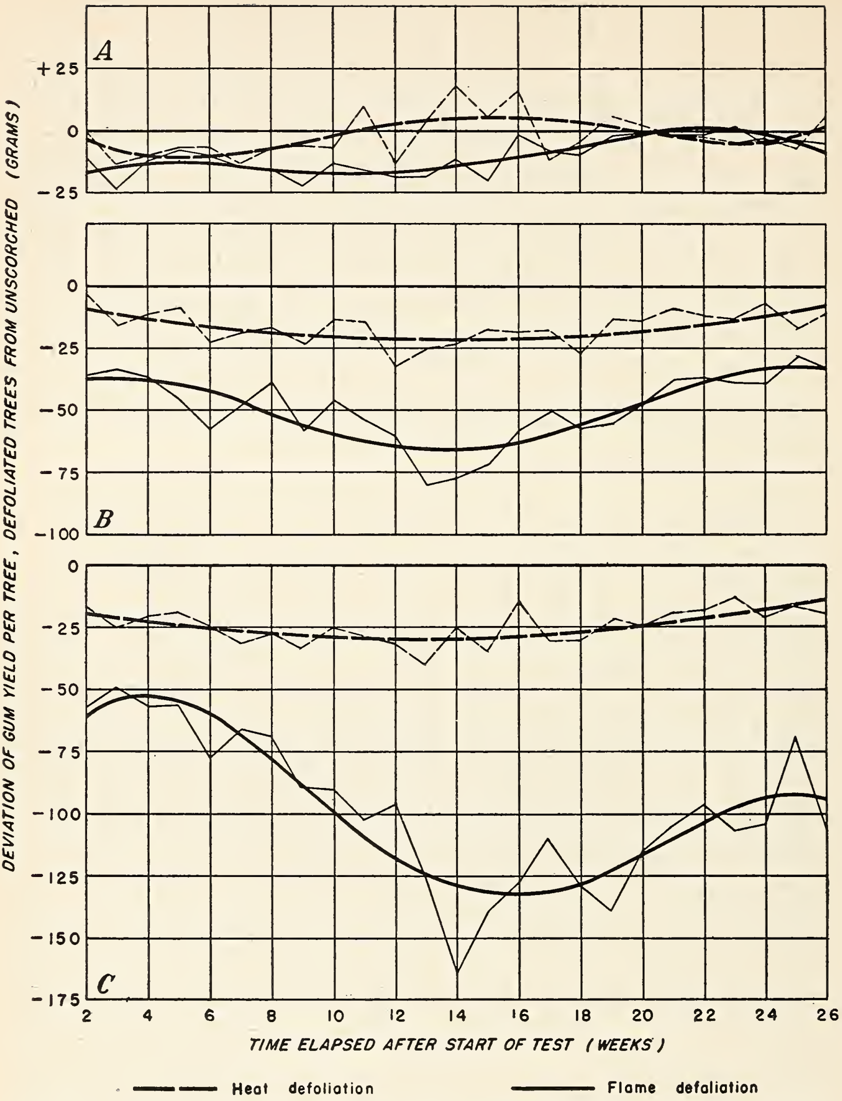

FIGURE 10.—Seven-day gum yield of slash pine as affected by heat and flame defoliation in May: *A*, Crowns one-third defoliated; *B*, crowns two-thirds defoliated; *C*, crowns completely defoliated.

for longleaf and slash pines, the flame-defoliation results for longleaf were adjusted by lowering the lower portion of the longleaf pine curve, as shown by the dotted line in figure 11.

The effect of this adjustment was to place the results of the two species on a comparable basis. The fact that the gum yields of the longleaf pine test trees were higher at low percentages of crown defoliation than corresponding yields of slash pine is attributed to the fact that the longleaf had smaller crowns, and so would normally show larger effects from equal degrees of defoliation.

TABLE 3.—*Loss in gum yield during the first year due to different degrees of defoliation by fire, by kind of defoliation and season of fire, in longleaf and slash pines*[1]

Cause of defoliation and season of fire	Pine species	Loss in gum yield[2] through crown defoliation of— One-third	Two-thirds	Three-thirds
		Percent	*Percent*	*Percent*
Heat:				
Late spring (June 1936)	Longleaf	....	8.5	....
Early spring (March 1937)	Slash	[3] 2.8	5.7	8.5
Late spring (May 1938)	do.	[3] 1.5	11.9	19.3
Flame:				
Early spring (March 1933)	Longleaf	11.7	19.3	31.6
Late spring (May 1938)	Slash	7.4	34.5	63.6

[1] The same group of trees was used in both of the longleaf pine tests, and also in all the slash pine tests. Longleaf pines averaged 35 years in age and 10 inches in diameter at breast height; slash pines averaged 25 years in age and 10 inches in diameter at breast height.
[2] All losses in yield were calculated on the basis of total gum flow in the 7 days following each weekly streak.
[3] Not statistically significant.

During the same season of year, destruction of needles by flame caused about three times the reduction of gum yields as killing the needles by heat, regardless of species. Insofar as the experimental burnings truly represented actual fires, this means that ordinary crown fires cause about three times the reduction of gum yield as suface fires that bring about an equal percentage of defoliation.

Again regardless of species, but for a similar cause and degree of defoliation, a late spring fire brought about twice as much loss in gum flow as an early spring fire. The importance of avoiding late spring or summer fires is therefore abundantly clear.

These results show clearly that the yield reaction to defoliation by fire is similar for slash and longleaf pines.

Loss in yield for the first season after fire is related to degree of defoliation in the following manner: Complete defoliation is nearly twice as serious as 2/3 defoliation, and 2/3 defoliation is about 4 times as serious as 1/3 defoliation (fig. 11). These relations hold for either flame or heat defoliation. Since flame defoliation is three times as serious as heat, the actual loss percent in yield for the former mounts to a rather high figure for complete crown denudation.

The loss in yield for the first season following complete defoliation by flame in early spring is about one-third, as compared with a loss of about two-thirds when such defoliation occurs in late spring.

The above results are for the first year after defoliation. By the end of the first season of turpentining, all test trees had sufficiently recovered to yield at approximately normal rates. It should be emphasized, however, that the most severe defoliation was not greater than would be expected in a mild crown fire. As previously stated, severe crown fires usually cause heavy tree mortality, and primarily for that reason turpentining is always deferred after such fires.

EFFECT OF STEM SCORCHING

Some scorching of tree stems, as well as tree defoliation, is caused by all except the lightest surface fires for which careful

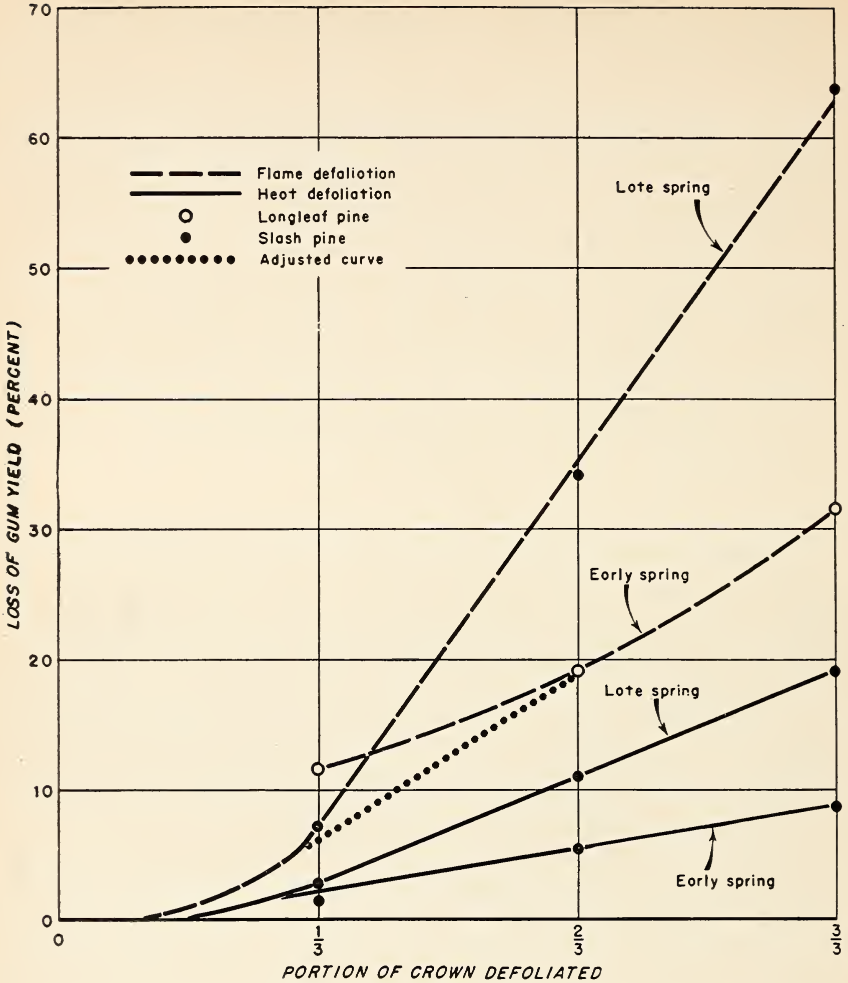

FIGURE 11.—Average loss in gum yield during the first season following defoliation by fire, by cause and degree of defoliation, season of occurrence of fire, and pine species.

control measures are taken. If stem scorching is severe enough to injure or kill gum-yielding tissues in the lower portion of the boles of slash and longleaf pines, it is certain to decrease gum production. Fire injury to stems, therefore, can be particularly serious in naval stores forests.

LIGHT BURNING

Naval stores men consider ordinary surface fires to be harmless to gum-yielding tissues unless unusual heat is generated, as by the burning of the turpentine faces. Much evidence supports their view. The custom, commonly followed for many years, of lightly burning over a new cupping area before faces are started apparently has no detrimental effects on the trees. Although the trees are not usually protected by the raking of fuel from around their bases, neither the condition of the chipping streaks nor the quantity of gum flow after such fires indicates impairment in yield. Moreover, though investigations have shown that light burning reduces bark thickness in longleaf pine (*12*, *18*), no published studies on either slash or longleaf pine have indicated that basal stem tissue is actually injured by such burning. This view is supported by the healthy appearance of stems of unturpentined pines on areas subjected to recurrent fires.

The important questions regarding the effect of stem scorching during light burning are: (1) How much injury is done to the unchipped portion of the stem when the turpentine face burns? and (2) can the decrease in gum flow be avoided or lessened by cutting the next streak above the injured area?

The effect from burning a turpentine face is similar to that caused by an overwinter rest period, and is locally known as "lightwood." During long intervals between chippings the wood at the top of a face becomes somewhat dry and gum from the resin passages spreads more or less into the dried wood on the surface of the streak. The streak then no longer looks fresh or white but becomes reddish in color. The gum soaking may extend an inch or more above the face during a normal winter rest period, and it is customary when beginning a new season's chipping to sacrifice that amount of face by cutting either an extra wide streak or a "jump streak."[13] Gum soaking occurs very rapidly after a turpentine face is burned. The possibility that fire-induced gum soaking would not extend very far above the face and that the wood affected could be eliminated by jump streaking led to experimentation to discover the effect of lightwooding and jump streaking on gum yield.

Measurements were made of gum yields in 1935 from longleaf pines which had been treated, prior to or just after start of chipping for the season, by these three methods:

1. No jump streaks; no faces burned.
2. No jump streaks; faces burned in March, 1 week in advance of chipping.
3. Two-inch jump streaks in advance of chipping; faces burned during the interval between the fifth and sixth streaks.

The longleaf pines were those used in the flame-defoliation test of 1933; they had, by 1935, completely recovered from damage by flame. Treatment 1 was given to the first group, treatment 2 to the second, and treatment 3 to the third and fourth. Turpentine faces were ignited with a blow torch, and care was taken to prevent the resulting fire from spreading to the ground cover. In general, the intensity of heat produced at the top of the turpentine faces was considered about equal to that caused by face burning during a severe surface fire (fig. 12). Regular chipping was begun about the middle of March and was continued at weekly intervals until November. Gum yields were weighed weekly.

A trend curve yield for each group was determined (fig. 13). The trend of the check group was developed by first correlating yield with maximum air temperature (for the first day of each

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[13] Cutting a "jump streak" or "jump peak" leaves a strip of bark about 2 inches high extending across the face between one year's chipping and the next.

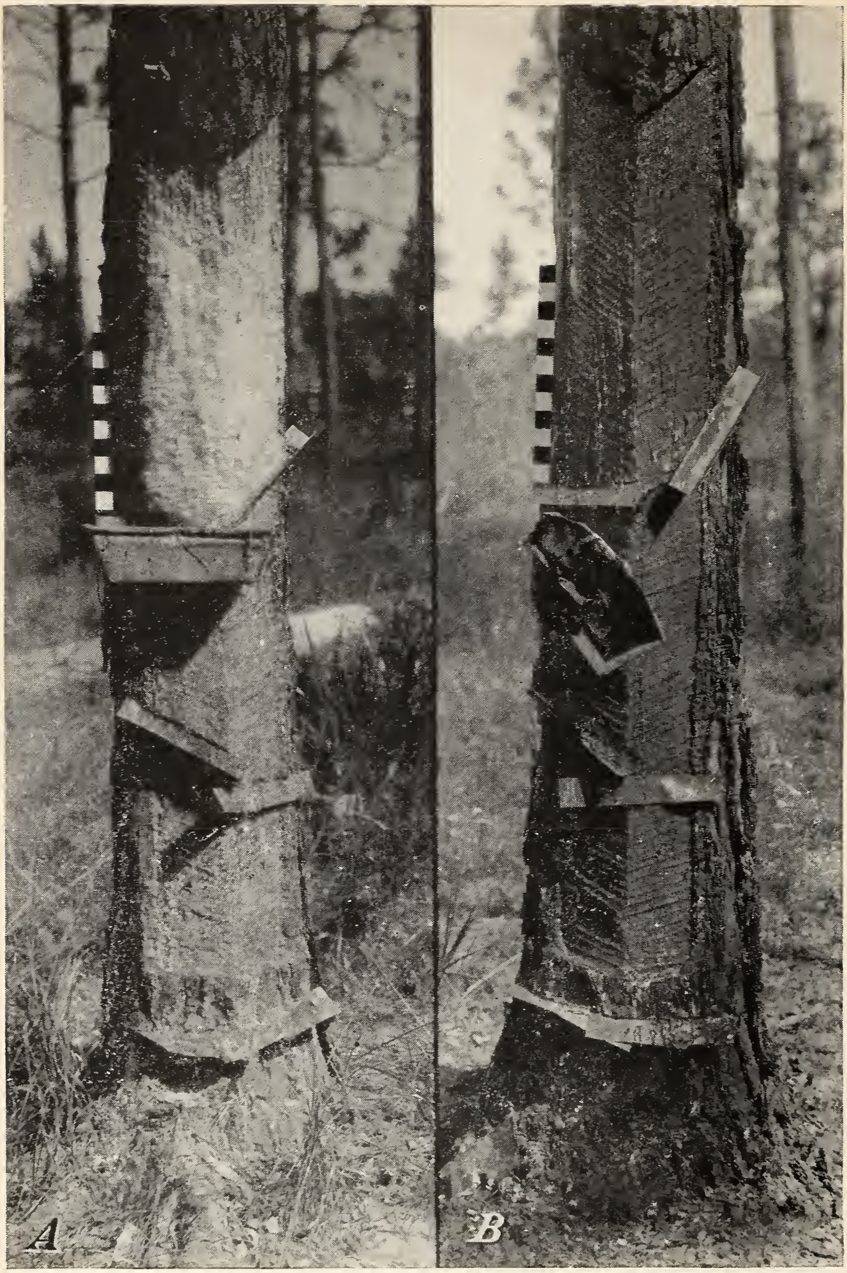

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FIGURE 12.—The most common damage from severe accidental surface fires is burning of the turpentine face. The same face is shown here *A*, before burning and *B*, after burning.

weekly streak) and the number of weeks elapsed after beginning of chipping, and then determining the net regression of time elapsed after starting of chipping, with temperature for the season held at its mean value. The curves shown for the three treatment groups represent yield differences between treated and check groups. They were determined by plotting the weekly average-yield differences between a treated group of trees and the check group.

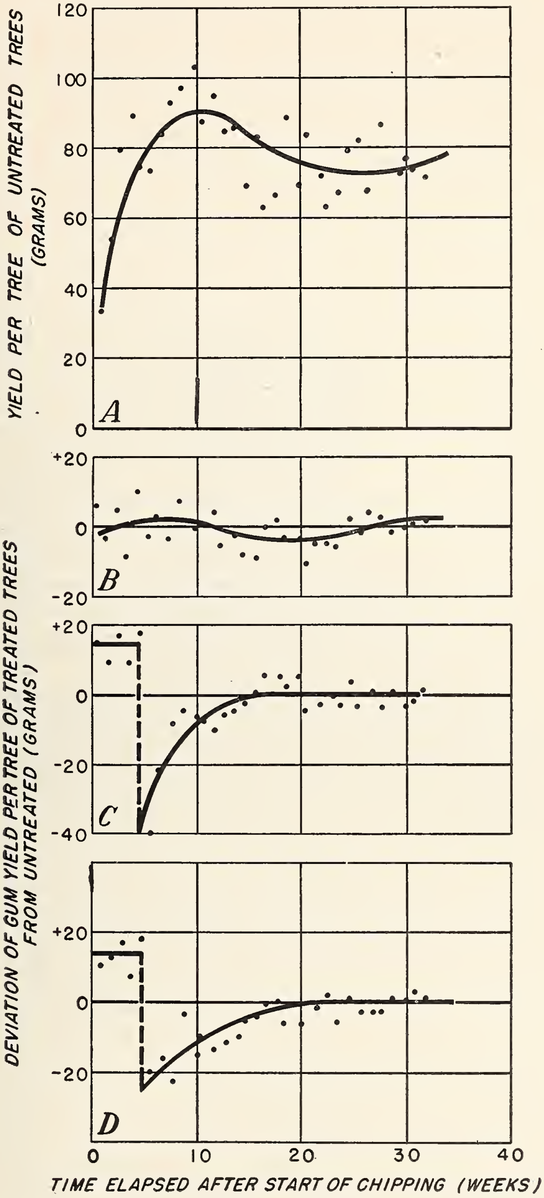

FIGURE 13.—Gum yield of longleaf pine as affected by turpentine-face fires and by jump streaking: *A*, Check group—no jump streaking and no face burning; *B*, face burning prior to beginning of chipping but no jump streaking; *C* and *D*, jump streaking prior to start of chipping, and face burning after fifth week of chipping.

Lightwooding due to overwinter exposure caused a marked loss in gum yield for the first streak, somewhat less for the second, and very little if any for the third (fig. 13, *A*). Since each streak was one-half inch in height, this indicates that the average distance to which lightwood was formed above the faces was 1 inch.

Lightwooding due to face burning extended upward into the unchipped wood between 1 and 5 inches, depending on whether the face burning was done prior to or after the beginning of the season's chipping. Face burning prior to chipping caused no additional loss in yield over that due to winter exposure (fig. 13, *B*). On the other hand, face fires applied after the beginning of chipping caused a marked loss in yield for the first streak following burning and a gradually decreasing loss in yield for at least the next nine streaks (fig. 13, *C* and *D*). Apparently face fires are more damaging during late spring than early spring.

Much of the loss in yield due to lightwood formation over the winter rest period was prevented by the jump streaking at the beginning of the chipping season. This was demonstrated by the high relative yields for the first few weeks, shown in figure 13, *C* and *D*. It is safe to assume that had 2 inches of wood been removed above the faces burned in late spring, before chipping was resumed, much of the loss shown in figure 13, *C* and *D* would have been prevented.

It is evident that jump streaking can be depended upon to prevent practically all of the loss in gum yield due to face fires prior to the opening of the turpentining season, and to lessen such loss during the turpentining season. The reduction in yield caused by face fires is slight—about 5 percent of the season's total—and of short duration.

HEAVY BURNING

A heavy crown fire is particularly destructive of turpentine trees. When a strong wind drives a fire through a stand during a period of low humidity, severe scorching of both stems and crowns is certain to result. This is especially true in stands undergrown with dense shrub and grass vegetation, which are common in the flatwood forests of north Florida and south Georgia wherever fire has been excluded for several years. Under such conditions many turpentine trees are killed outright or are weakened to such a point that they subsequently die.[14] These trees, of course, are a total loss. Many others suffer severe stem wounds that result in the dying or drying up of segments of sapwood, often just above turpentine faces. This is known to the industry as dry face.

The extent to which turpentine trees may be killed by a particularly heavy fire is illustrated by the fire of April 1934 in southeast Georgia, which in one afternoon burned approximately 15,000 acres that had been under protection for 15 years. About 50 percent of the slash and longleaf pines that were being turpentined and perhaps 80 percent of the 15-year-old second growth were killed. The mortality varied greatly by locality, depending upon the density and character of the pine stands and of the grassy and woody undergrowth. The fire killed all turpentine trees and all young pines on areas having a heavy rough, but none of the turpentine trees and only a few of the young pines on areas having a light rough.

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[14] Badly scorched trees frequently are attacked by *Ips* beetles during the first year following fire (*15*).

This area was studied in detail, with the cooperation of the naval stores operator, in March 1936 (approximately 2 years after the fire) to determine the extent of dry face in turpentine trees that survive a particularly heavy fire, and to explore the factors associated with varying amounts of fire-caused dry face. The procedure adopted by the operator was to make a test jump streak above each burned face to ascertain the minimum "jump" required to place the chipping in wood sufficiently live for favorable gum flow. His plan was to make successively higher trial cuts, until not more than about one-fourth the surface of the cut was in dry wood or a height was reached (usually about 5 feet) beyond which it was not practicable to go (fig. 14). Since all the trees in the study had either 1- or 2-year faces at the time of the fire,

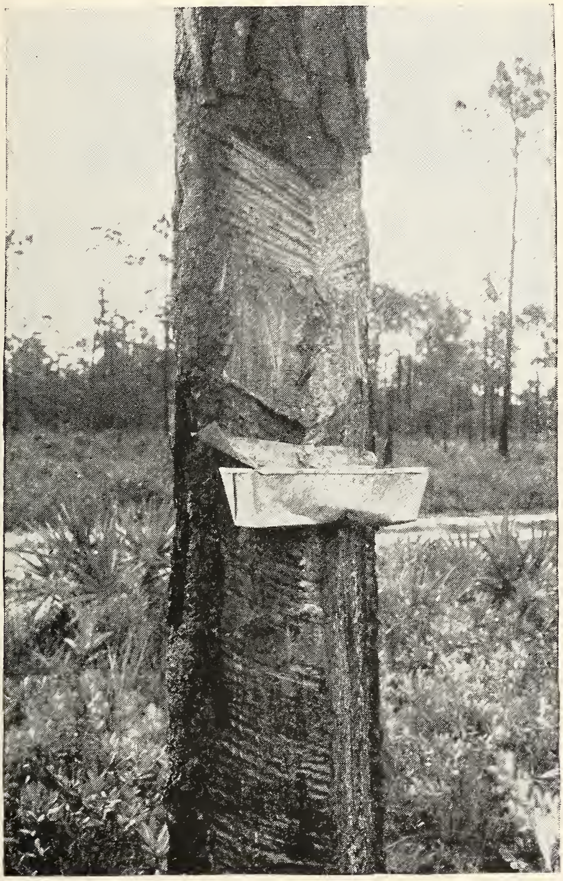
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Figure 14.—Jump streak such as was made on the southeastern Georgia study area at the time turpentining was resumed, 2 years after the severe fire, to avoid excessive dry face.

TABLE 4.—*Particulars of dry face resulting from a severe crown fire*[1]

Item	Dry-face class of jump streak	
	Less than 25 percent	25 percent or more
Trees examined[2] ... Number	291	138
Do. ... Percent	68	32
Longleaf pine ... do.	15	18
Slash pine ... do.	85	82
Average dimensions:		
Height of jump streak ... Inches	2.25	5+
Diameter breast high ... do.	11.3	10.6
Crown length at time of fire in terms of tree height ... Percent	33	30
Height of charred bark ... Feet	14.2	14.4
Average proportion of dry face in jump streak ... Percent	5.3	47.5
Position of face with reference to wind stream:		
Leeward ... do.	28	57
Windward ... do.	45	17
At right angles ... do.	27	26

[1] Based on data from a sample survey of a 15,000 acre area in southeast Georgia burned over in April 1934. The survey was made in 1936, at time of resumption of commercial chipping. The "25 percent or more" class includes some trees that were considered unprofitable and so were abandoned.

[2] Each tree had one first- or second-year low face in progress at time of fire.

height of jump streak above the top of the burned face ranged from a few inches to several feet. The data for representative sample strips are summarized in table 4.

Of the 429 trees examined, 68 percent were chipped from jump streaks having less than a quarter of their chipped surfaces in dry, unproductive wood. The remaining 32 percent either were chipped from jump streaks having greater portions of their surfaces in dry face, or were abandoned because they were considered unprofitable. The average amount of dry face in the streaks less than a quarter in unproductive wood was 5.3 percent; in the others, it was 47.5 percent. In the former group, height of jump streak averaged 2.25 inches, and was never more than 5 inches. In the latter group it was never less than 5 inches and was usually much greater. Among the other factors considered, species, size of tree, tree vigor (as indicated by length of crown at the time of the fire divided by height of tree), height of charred bark, and position of face with respect to wind at the time of fire, only the last appeared to be markedly related to the amount of dry face. Thus, in the group having more than a quarter dry face, 57 percent of the trees had faces away from the fire and only 17 percent had faces toward the fire. The heavier damage to stem tissues on the leeward side is attributed to focusing of heat on that side as flames were whipped around the tree. Such damage was illustrated by the fact that many smaller, and hence thinner-barked, pines on the study area had long stem scars plainly visible and all facing in the same direction—away from the fire (fig. 15).

It is evident that there is no need to make trial jump streaks higher than 5 inches above a burned face to determine the dry face condition of a tree after a severe fire. If the amount of dry face revealed at a 5-inch height is in excess of 25 percent of the cut surface of the jump streak, there is not much hope that it will be less at a greater height.

Actual loss in yield as a result of dry face was not measured. Occurrence of some dry face in stands of turpentined trees is not uncommon even in the absence of fire. It may be concluded, there-

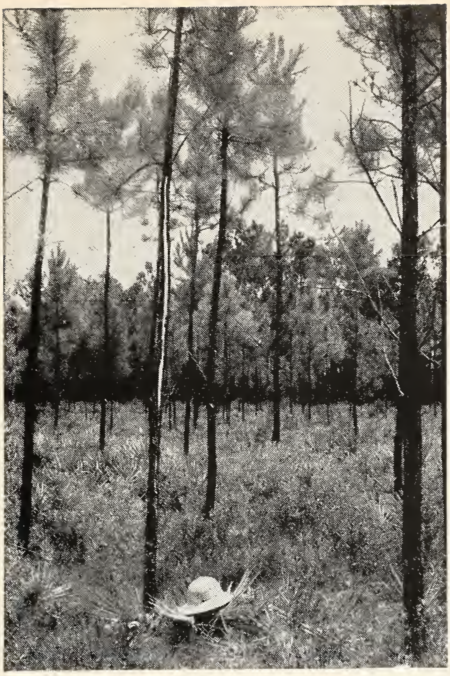

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FIGURE 15.—After a severe fire, long stem scars frequently are found on the sides of young saplings facing away from the direction from which the fire approached. This photograph, taken about 3 years after the southeast Georgia fire, shows tree in foreground with stem scar.

fore, that 68 percent of the surviving trees in the class having an average of only 5.3 percent dry face were not seriously affected by the stem scorching. On the other hand, 32 percent of the trees were so severely dry-faced (more than 25 percent) that their continued working from established faces was considered unprofitable.

If a new face is started on the back side of a tree heavily dry-faced as a result of fire, how much dry face is to be expected? It is believed that a back face can be so placed as to avoid any fire-injured tissues since considerable freedom may be exercised in locating it.

Whether turpentining after heavy scorching should be deferred for 2 years or more has been a moot question in the industry. Some operators advocate long periods of rest for trees burned in a heavy crown fire and few resume operations in less than 2 years. That it is wise to defer turpentining under such conditions is indicated by the studies of Cary (*2*) and Gerry (*6*), who found that during the first year, with turpentining, many trees died, and some others, although they remained alive, ceased to yield because of dry face. While not all this tree and face mortality can be attributed to uninterrupted turpentining, it is reasonable to ascribe at least some of it to this cause. The trees in the southeast Georgia study were not turpentined until 2 years after the fire. By that time, the surviving trees had developed new foliage, comparable to that of unburned trees, and they appeared to be growing vigorously. It may be concluded that a 2-year deferment of turpentining after a severe crown fire is ample.

COMBINED EFFECT OF SURFACE FIRE, DEFOLIATION, AND STEM SCORCHING

Each of the experiments discussed so far dealt with a single effect of fire on turpentine trees, whereas under field conditions only a very light surface fire would be so limited in effect. Could the results of the experimental fires—effect of ground-cover removal, tree defoliation, and bole injury—be so integrated as to form a basis for a true evaluation of the full effect of fire on turpentine yields? The question is appropriate only for fires that cause damage that is not severe enough to necessitate deferment of turpentining. The answer lies in checking these effects against an accidental fire in which the effects of several types of comparatively light damage are combined.

Such a fire occurred in November 1934, in a longleaf pine stand containing trees in their second year of turpentining. During the following winter the turpentine trees were classified into three groups according to character of defoliation and extent to which crowns were denuded (all faces had been burned). Group 1 contained 11 trees defoliated to a moderate degree by heat (about one-third defoliation); group 2, 32 trees defoliated to an extensive degree by heat (about two-thirds defoliation); group 3, 6 trees defoliated extensively by heat and to some extent by flame. Following the cutting of a jump streak on each tree, turpentining of the test trees was begun in March 1935 and continued for one season—until November of that year. Gum yields were analyzed by first computing the regression equation of yield on tree size and growth rate, and then averaging the residual yields by tree-defoliation class. The results of this analysis compared with the results obtained in the burning experiments are shown in table 5.

Table 5.—*Check of integration of experimental findings regarding effects of different types of burning on gum yield in following year*

Type of burning	Findings on area burned over by accident[1]		Experimental findings[2]	
	Loss in gum yield	Basis, trees	Loss in gum yield	Basis, trees
	Percent	*Number*	*Percent*	*Number*
Type 1:				
Burning of ground cover	....	....	+4.0	178
Moderate heat defoliation	....	....	−2.8	65
Total	[3] −2.4	11	[3] +1.2	....
Type 2:				
Burning of ground cover	....	....	+4.0	178
Extensive heat defoliation	....	....	−5.7	65
Total	[3] −2.7	32	[3] −1.7	....
Type 3:				
Burning of ground cover	....	....	+4.0	178
Extensive heat defoliation and some flame defoliation	....	....	−19.3	20
Total	[4] −11.7	6	−15.3	....

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[1] The trees were longleaf pines in second year of turpentining. The fire occurred in November 1934.

[2] Values taken from tables 1 and 3, without distinction as to species.

[3] Not statistically significant.

[4] Standard error ±5.

No essential difference in results was found for any of the three classes of fire damage. A statistically significant value for the effect of fire on the gum yield was not obtained by either method for groups 1 and 2. Apparently, for these groups (containing, respectively, only trees moderately and extensively defoliated by heat from the ground fire) the favorable response of the yield to the burning of ground cover was cancelled by its unfavorable response to heat defoliation. Only light crown fires caused a net detrimental effect on yield (of group 3). The net reduction in yield was 11.7 percent after the accidental fire and 15.3 percent as determined experimentally. The difference is not statistically significant, since the 11.7 has a standard error of 5 percent. Moreover, the 15.3 percent is probably too high, because this value is the result of flame defoliation solely, whereas most of the defoliation from the accidental fire was caused by heat from the ground fire.

It is evident that the combined effect of ground-cover burning and tree defoliation caused by light fires can be adequately determined by adding (algebraically) the results obtained in the experiments described in the previous sections.

APPLICATION OF RESULTS

The results of this study definitely show that fire has a great influence on the gum yield of slash and longleaf pines, and that this influence varies with the kind and severity of burning. This knowledge can be used by naval stores producers in appraising fire damage, in regulating chipping practice, in planning controlled burning, and in other ways.

Classification of Fires

An important point brought out by this study is that fires can be classified with respect to effects on gum production relatively soon after they occur. The principal basis of classification is the cause and degree of defoliation. The extent of needle loss can be estimated within a few days after a fire that burns off foliage, and within 2 weeks after one that causes heat killing of foliage. Heat-killed needles turn brown gradually and remain on the tree for several weeks. Tree mortality may not reveal its full extent until toward the end of the first growing season; face mortality may be gaged by trial chippings a few weeks after the fire, although this test is generally made at a later date when turpentining is resumed. Tree and face mortality usually occur only in very severe crown fires of the "blow-up" or conflagration type.

Defoliation probably may be determined accurately enough from an inspection of sample strips of the burned area. An estimate based on a small sample should suffice, since the action contemplated, such as uninterrupted turpentining or deferment for 1 or 2 years, ordinarily must be taken for the area as a whole. Usually if some of the trees of a burned stand cannot be worked it is not feasible to work any.

Four fire classes are recognized as a basis for determining naval stores damage, the best time to resume turpentining, and the degree of control required in using fire for management purposes. These are as follows:

Class 1.—Typical of a successfully controlled burn. Heat defoliation is absent or affects not more than 10 percent of the crown of a turpentine tree. The effect is essentially that of a light accidental surface fire and the influence on the yield depends upon the depth of the insulating rough that was consumed. For a typical flatwoods area, such as that of the present study, an increase of about 4 percent in gum yield may be expected for the first season of turpentining following a winter burn of this class; during the second season the yield advantage may be diminishing or eliminated entirely as the vegetative cover is renewed. Slash and longleaf pines may be expected to react alike.

Class 2.—Typical of a moderately heavy surface fire, often the mis-called "light burning." Heat defoliation affects from 10 to 50 percent of the crown of a turpentine tree. A slight reduction in yield due to defoliation must be expected to cancel any increase caused by burning of the ground cover. The net effect on gum yield is probably nil. Slash and longleaf pines may be expected to react alike.

Class 3.—Typical of a heavy surface fire or a light crown fire of the accidental sort. The individual turpentine trees exhibit defoliation up to 50 or even 100 percent, of which 60 percent may be due to burning off of the needles and the remainder to heat killing. The effect is a reduction in yield probably averaging about 25 percent (ranging from 15 to 35 percent) for the first season of turpentining following a winter or early spring fire, or double that for a late spring fire. Yield recovery is rapid, however, regardless of season of occurrence, and yield may be expected to reach normal by the second season. Slash and longleaf pines may be expected to react alike.

Class 4.—Typical of a heavy crown fire. Individual turpentine trees exhibit 100 percent defoliation, most of it from burning. Tree mortality may be light or very heavy. The effect on gum yield, should the remaining live trees be turpentined without a rest period, would be great—probably a reduction of about 60 percent for the first season and some reduction for the second season. Slash and longleaf pines may be expected to react alike.

Stem scorching may be severe. This injury is usually localized in a narrow (but sometimes long) vertical scorch. If a long scorch occurs directly above an existing face, injured tissues will unavoidably be part of any future streak. If the injury affects more than 25 percent of the streak, continued working is considered unprofitable. Where the cambium scorching is not above the face but to the side, the chances are fair that it can be avoided when a new face is installed.

CONTROLLED BURNING

The finding that gum yield was increased by burning of ground cover only has a possible application in controlled burning. While the increase is small and not likely to be an impelling reason for the controlled use of fire, it helps to balance the cost of burning.

"Controlled burning," as used in the naval stores region, may be defined as burning planned for the reduction of fire hazard and so carried out, in respect to the extent of spread and heat intensity, that the objective is accomplished with the least practicable injury to the stand.

The heavy roughs built up under fire exclusion are generally on areas characterized by understocked stands of mature pines and dense, luxuriant undergrowths composed of grass, vines, shrubs, and young pines. Because on such areas the danger of fierce accidental fire and resultant great damage is high, it is usually advisable to reduce the heavy fuel periodically by carefully controlled fires. Burning for this purpose is ordinarily begun when the slash pine saplings have reached an age of about 5 years and a height of at least 5 feet. A thinning operation frequently precedes the burning (fig. 16). The decision to use fire is usually based on the degree of fuel hazard, height of the trees to be protected, and cost.

In figuring costs, the effect of controlled burning on the yield should receive attention. The first controlled burn in an open stand reproducing to young slash pines is likely to be costly because of the great care involved. As the young trees develop, the need for extreme care lessens and the cost is likely to be reduced. Control adequate to protect young growth from damage is surely adequate to protect turpentine trees from extensive defoliation such as would lower yields. Accordingly, an increase in gum yield may be expected. If the increase is 4 percent, as indicated by the results of this study, the extra yield in terms of annual lease value or "stumpage" income would average about 0.25 cent per tree, varying with the productivity class and the lease price of the timber (table 6). Thus, suppose that the lease price is 25 percent of gross returns; that the productivity class is 50 units of gum products per crop of 10,000 faces; and that the price per unit of naval stores is $50. The increase then is 4 percent of 50 units, or 2 units per 10,000 turpentine faces, that is, $100. Since the lease price is 25 percent, $25 is credited to "stumpage," or 0.25 cent per face. If only one face is worked at a time this means 0.25 cent per tree.

Table 6.—*Gain per acre in value of naval stores lease accruing from a 4-percent increase in gum yield, by density of stand and market price of gum*[1]

Turpentine trees per acre (number)	Gain in value, per acre, at naval stores price of—									
	$50 per unit, when units per crop number—					$60 per unit, when units per crop number—				
	40	45	50	55	60	40	45	50	55	60
	Cents	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*
20	4.0	4.5	5.0	5.5	6.0	4.8	5.4	6.0	6.6	7.2
30	6.0	6.8	7.5	8.2	9.0	7.2	8.1	9.0	9.9	10.8
40	8.0	9.0	10.0	11.0	12.0	9.6	10.8	12.0	13.2	14.4
50	10.0	11.2	12.5	13.8	15.0	12.0	13.5	15.0	16.5	18.0
75	15.0	16.8	18.8	20.6	22.5	18.0	20.2	22.5	24.8	27.0
100	20.0	22.5	25.0	27.5	30.0	24.0	27.0	30.0	33.0	36.0

[1] Assumed price of lease is 25 percent of gross returns. A unit is 1 barrel (50 gals.) of turpentine plus the corresponding amount (about 1,400 pounds) of rosin which may be manufactured along with it. A crop is 10,000 faces.

If the area burned has only 20 trees per acre being turpentined (which is now about the average for the region as a whole), the extra yield caused by the controlled fire will be worth 5 cents per acre. The returns from burning increase with the number of trees under turpentining, reaching 25 cents for 100 trees per acre under the above prices and yield. Increases in lease value,

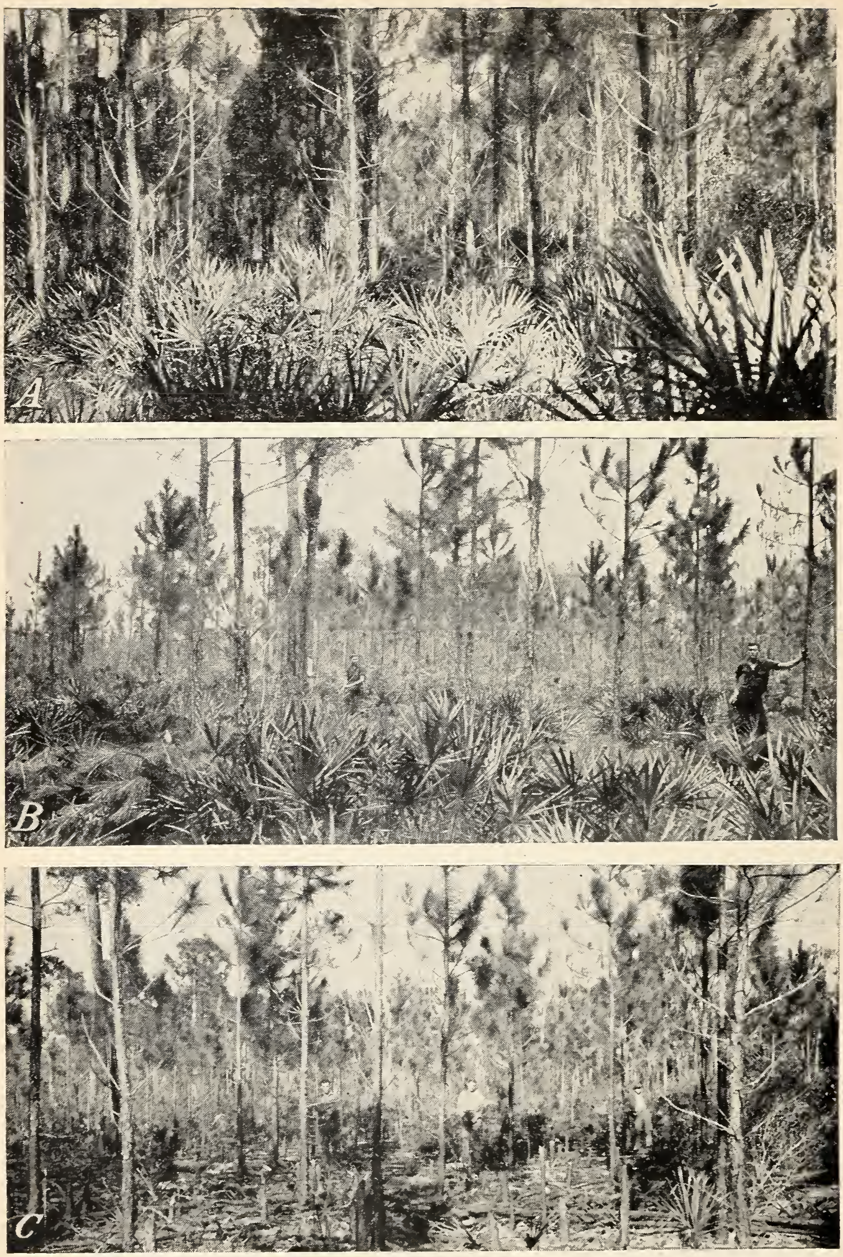

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Figure 16.—Stand of slash pine, 6 to 8 years old, subjected to thinning and reduction of slashings and ground cover in a controlled surface fire. (*A*), The original dense stand and heavy rough, presenting a high risk of damage and loss; (*B*), Same area after the thinning operation; (*C*), Several days after controlled burning. The freshly cut thinned trees made a terrific smudge; but the stand showed no defoliation by flame or even indications of defoliation by heat.

by number of trees per acre and by productivity and naval stores price classes, computed on the basis of an expected increase in gum yield of 4 percent during the first season following a controlled winter fire, are presented in table 6.

Estimates of the cost of controlled burning vary widely, depending primarily upon the accumulated rough and the cost of raking around turpentine trees. Commercial trials in 1944 have ranged from 20 to 25 cents or more per acre with most of the cost taken up by raking. If a means can be found to lessen the cost of raking or to do away with the need for this protective operation, it is conceivable that, as the young stands develop in size, a point will be reached where returns equal costs. Moreover, there is the further possibility that the interval between controlled burns may be shortened as stands develop and the danger of inhibiting growth by defoliation decreases. Under a favorable cost-benefit ratio, the desirability of shortening the interval is obvious, since the controlled-burning benefit (in gum yield) wears off after the first season, or as soon as a cover is reestablished.

It would be best, however, to proceed slowly in any attempt to increase the yield by use of fire. To be a successful tool in forest management, controlled burning must have definite limitations, and these should be constantly kept in mind. The fire obviously must be confined to one's own land. There will probably be areas within any forest property on which it is unwise to use fire at certain times, if at all. The need to protect new reproducing areas also is obvious and protection of watershed values on rolling land must not be overlooked.

Another limitation, often forgotten, is the need of avoiding crown damage to large timber. If the heat of the fire defoliates 25 percent or more of the crowns, yields will be slightly decreased and growth retarded. No yield advantage would result from a return to uncontrolled annual burning, or to "light burning." Such burning, as indicated in table 7, may cause as much as 44 percent heat defoliation. This would more than cancel any gain due to the burning of ground cover.

TABLE 7.—*Heat defoliation of slash and longleaf pines caused by the traditional type of annual "light burning"*[1]

Height class of pines (feet)	Trees not defoliated		Defoliation ranging from 1 to 9 percent			Defoliation amounting to 10 percent or more		
			Trees so affected		Average extent of defoliation per tree	Trees so affected		Average extent of defoliation per tree
	Number	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*
1.0- 6.0...	0	0	0	0	0	136	18.28	92.87
6.1-12.0...	2	.27	6	.81	4.83	78	10.48	78.73
12.1-25.0...	13	1.75	8	1.07	5.38	124	16.67	60.47
25.1-up....	71	9.54	98	13.17	4.60	208	27.96	43.81
Total.....	86	11.56	112	15.05	....	546	73.39	....

[1] On 60 plots of 1/10 acre each, selected at random in February 1936 on burned-over areas in northeast Florida.

Whereas the desire to increase the yield may be an important reason in deciding on a burning program, it is only one of several factors that must be considered, the relative importance of which vary with the situation. During the regeneration period the need to avoid damage to reproduction and young growth dictates the starting date and controls the cost. An overstory of turpentine trees can help pay the high initial cost. Later on, as requirements of reproduction become less exacting, the effect on gum yield becomes a more prominent factor in deciding on controlled burning.

TURPENTINING PRACTICE

One of the clearest implications of this study is that turpentining should be postponed after a severe crown fire to avoid a heavy loss in gum yield. A winter class 3 fire—one causing defoliation by flame and heat of 50 to 100 percent of the crown—reduces yield by about 25 percent during the first season. From a class 3 fire in late spring or early summer the first-season reduction is about 50 percent. A class 4 or severe crown fire in late spring or early summer not only causes a reduction of 60 percent in the first season but some reduction in the second season as well. On the other hand, when damage is less than that of a class 3 fire there is not enough reduction in yield during the first season to call for deferment of turpentining.

A reason frequently given in the industry for postponing turpentining after a heavy fire is avoidance of unnecessary tax on the recovering trees. Observations in this study and other evidence support this. The point is not of great importance, however, since the reduced yields alone are sufficient reason. The cost of deferring income is about equal to, if not less than, the loss in lease value that would result if the trees were worked.

Tree mortality and turpentine-face mortality are two other forms of damage for which it is necessary to make adjustments in naval stores practice. The former does not present any special difficulties, although the loss may indeed be heavy; a dead tree is obvious and is simply counted out of the operation. Face mortality, on the other hand, is not always easy to determine. Fortunately, it does not occur except after heavy fires of the worst type.

In a light fire of class 1 or class 2, a turpentine face may burn briskly for a few minutes but the heat is seldom sufficient to injure the stem tissue above the face. At most, 2 to 10 streaks above the burned face are affected, and as in the present experiments, the effect on gum yield is not unlike that from overwinter gum soaking. Either a wide initial streak or an ordinary jump streak should be sufficient to eliminate most if not all of the ill effects, and is the only modification of turpentine practice required.

A method of estimating the dry face resulting from a heavy fire is illustrated by the procedure employed on the study area in southeast Georgia. Two years after the heavy fire, each surviving tree was tested for dry face by first cutting an ordinary jump streak. If the streak was three-fourths free of dead tissue (i.e., less than one-quarter in dry face) regular chipping continued from that point. If not, jump streaks were cut at progressively higher levels until that proportion of live wood was encountered or further chipping would extend the face height beyond the practical limit. Actually, as finally determined, it is not necessary to test higher than 5 inches above the old face; if the streak is not three-fourths free of dead tissue at that height, the chances are small that a greater height would better the condition.

The present study has provided a basis for estimating timber losses in terms of naval stores values, whether these losses are caused by (1) severe defoliation, (2) actual killing of trees, or (3) injury to turpentine faces. The first and least serious kind of loss is the most common, and often occurs alone. The second and third result only from particularly heavy fires, often occur together, and, of course, always in conjunction with the first.

When turpentining is deferred because of heavy tree damage from an accidental fire, appraisal of loss is simple. The loss is due to a deferment of income, and to tree and face mortality. This may be illustrated by the following example. Suppose a class 4 fire, occurring in the early spring (when turpentining begins on newly cupped round timber) causes such severe defoliation that turpentining must be suspended for 2 years to avoid mortality and a heavy reduction in gum yield. Suppose, further, that the timber has a calculated turpentining life of 12 years—6 years for a front face and 6 years for a back face—and that this full turpentining life still remains after the 2-year wait. The loss in lease value then is clearly the difference between the present worth of prospective annual yields for a 12-year period if no fire had occurred and the present worth if the yields begin 2 years hence. Thus, assuming a lease value of 25 percent of the gross returns, a naval stores price per unit of $50, and a productivity of 50 units per crop (10,000 faces), the annual lease return is 6.25 cents per tree. At an interest rate of 3 percent, the present worth of 12 returns is 62.21 cents. Discounted 2 years because of the delay caused by fire, the present value is 58.64 cents. The difference, 3.57 cents, represents the loss due to the fire. This amounts to about half the lease value for 1 full year of turpentining.

If turpentine trees are killed by fire or die because of subsequent *Ips* beetle attacks, the full lease value of the trees, or the present worth of the 12 annual yields—62.21 cents per tree—is lost.

If stems are injured during the turpentining period so that some faces are rendered unproductive, losses in lease value may be estimated according to the same procedure. Thus, if the damage occurs at the beginning of the fourth year of turpentining, the loss is the present value of the 3 remaining years of face life, or 17.68 cents per tree.

Calculated losses due to defoliation are presented in table 8 by naval stores price and productivity class, and those caused by tree or face mortality in table 9. It is believed that these two tables cover the normal range in conditions and hence provide basic tree values needed in an appraisal of loss due to the reduction of naval stores values by fire.

The naval stores productivity classes shown in the tables range from 40 units to 60 units per crop. The yield class of a given tract of timber is readily determinable from records of past gum production.

Ordinarily an average productivity class will suffice for the purpose of computing future income. If more refinement is desired in projecting yield, the following suggestions, based on unpublished data of the Southern Forest Experiment Station, should prove helpful: (1) Back faces produce slightly more than front faces, other things (especially face widths) being equal, because

TABLE 8.—*Calculated loss*[1] *in present value of naval stores lease resulting from defoliation by a severe fire*[2]

TURPENTINING POSTPONED 1 YEAR (CLASS 3 FIRE)

Turpentining years remaining at time of fire (number)	Loss, per tree, at naval stores prices of—									
	$50 per unit, when units per crop number—					$60 per unit, when units per crop number—				
	40	45	50	55	60	40	45	50	55	60
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1	0.14	0.16	0.18	0.19	0.21	0.17	0.19	0.21	0.23	0.25
2	.28	.31	.35	.38	.42	.33	.38	.42	.46	.50
3	.41	.46	.51	.57	.62	.49	.56	.62	.68	.74
4	.54	.61	.68	.74	.81	.65	.73	.81	.89	.97
5	.67	.75	.83	.92	1.00	.80	.90	1.00	1.10	1.20
6	.79	.89	.99	1.08	1.18	.95	1.07	1.18	1.30	1.42
7	.91	1.02	1.13	1.25	1.36	1.09	1.22	1.36	1.50	1.63
8	1.02	1.15	1.28	1.41	1.53	1.23	1.38	1.53	1.69	1.84
9	1.13	1.28	1.42	1.56	1.70	1.36	1.53	1.70	1.87	2.04
10	1.24	1.40	1.55	1.71	1.86	1.49	1.68	1.86	2.05	2.24
11	1.35	1.52	1.68	1.85	2.02	1.62	1.82	2.02	2.22	2.43
12	1.45	1.63	1.81	1.99	2.17	1.74	1.96	2.17	2.39	2.61

TURPENTINING POSTPONED 2 YEARS (CLASS 4 FIRE)

Turpentining years remaining at time of fire (number)	$50: 40	$50: 45	$50: 50	$50: 55	$50: 60	$60: 40	$60: 45	$60: 50	$60: 55	$60: 60
1	0.28	0.31	0.35	0.38	0.42	0.33	0.38	0.42	0.46	0.50
2	.55	.62	.69	.76	.82	.66	.74	.82	.91	.99
3	.81	.91	1.01	1.12	1.22	.97	1.10	1.22	1.34	1.46
4	1.07	1.20	1.33	1.47	1.60	1.28	1.44	1.60	1.76	1.92
5	1.31	1.48	1.64	1.81	1.97	1.58	1.77	1.97	2.17	2.37
6	1.55	1.75	1.94	2.14	2.33	1.87	2.10	2.33	2.57	2.80
7	1.79	2.01	2.24	2.46	2.68	2.15	2.41	2.68	2.95	3.22
8	2.01	2.27	2.52	2.77	3.02	2.42	2.72	3.02	3.32	3.63
9	2.23	2.51	2.79	3.07	3.35	2.68	3.02	3.35	3.69	4.02
10	2.45	2.75	3.06	3.37	3.67	2.94	3.31	3.67	4.04	4.41
11	2.66	2.99	3.32	3.65	3.98	3.19	3.59	3.98	4.38	4.78
12	2.86	3.21	3.57	3.93	4.29	3.43	3.86	4.29	4.71	5.14

[1] According to the formula

$$\text{Loss} = \frac{i[(1+p^n)-1]}{p(1+p^n)} - \frac{i[(1+p)^n-1] \div (1+p)^d}{p(1+p)^n},$$

in which i = naval stores lease price per year (25 percent of gross returns), p = rate of interest (3 percent), n = number of years of turpentining left at time of fire, and d = number of years turpentining is postponed owing to the fire.

[2] A unit is 1 barrel (50 gallons) of turpentine plus the corresponding amount (about 1,400 pounds) of rosin which may be manufactured along with it. A crop is 10,000 faces.

TABLE 9.—*Calculated loss*[1] *in present value of naval stores lease resulting from tree or turpentine-face mortality after a severe crown (class 4) fire*[2]

Turpentining years remaining at time of fire (number)	Loss, per tree, at naval stores price of—									
	$50 per unit, when units per crop number—					$60 per unit, when units per crop number—				
	40	45	50	55	60	40	45	50	55	60
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1	4.85	5.46	6.07	6.67	7.28	5.83	6.55	7.28	8.01	8.74
2	9.57	10.76	11.96	13.16	14.35	11.48	12.92	14.35	15.79	17.22
3	14.14	15.91	17.68	19.45	21.21	16.97	19.09	21.21	23.34	25.46
4	18.59	20.91	23.23	25.56	27.88	22.30	25.09	27.88	30.67	33.45
5	22.90	25.76	28.62	31.49	34.35	27.48	30.91	34.35	37.78	41.22
6	27.09	30.47	33.86	37.24	40.63	32.50	36.57	40.63	44.69	48.75
7	31.15	35.05	38.94	42.83	46.73	37.38	42.05	46.73	51.40	56.07
8	35.10	39.49	43.87	48.26	52.65	42.12	47.38	52.65	57.91	63.18
9	38.93	43.80	48.66	53.53	58.40	46.72	52.56	58.40	64.24	70.07
10	42.65	47.98	53.31	58.65	63.98	51.18	57.58	63.98	70.37	76.77
11	46.26	52.05	57.83	63.61	69.39	55.52	62.46	69.39	76.33	83.27
12	49.77	55.99	62.21	68.43	74.66	59.72	67.19	74.66	82.12	89.59

[1] According to formula

$$\text{Loss} = \frac{i[(1+p)^n-1]}{p(1+p)^n},$$

in which i = naval stores lease price per year (25 percent of gross returns), p = rate of interest (3 percent), and n = years of turpentining lost.

[2] A unit is 1 barrel (50 gallons) of turpentine plus the corresponding amount of rosin (about 1,400 pounds) which may be manufactured along with it. A crop is 10,000 faces.

of the increase in tree size in the interim; and (2) within a 6-year span, beginning with virgin faces, the successive annual yields bear the relation respectively of 100, 106, 103, 98, 93, and 88. No distinction need be made between slash and longleaf pines in calculating relative annual yields.

The lease value of turpentine timber is commonly calculated either as a flat sum per face or as a certain percent of gross returns, based on the productivity of the timber in question, either from expected yield, or from actual yield. In computing losses as shown in tables 8 and 9, the naval stores lease values were taken as 25 percent of gross returns. In practice, the percent varies from 15 to 35, depending upon accessibility and other factors. Should estimates of loss be desired on a different percent basis than that used in the tables, they can be readily calculated.

Prices of naval stores have in the past varied widely from year to year, but the average falls within the $50 to $60 range shown in tables 8 and 9.

The rate of interest used in computing future and discounted values controls the amount of indicated loss. Use of a higher rate would indicate a lower present worth; 5 percent would give 55.4 cents, as compared to 62.2 cents at 3 percent. Hence, in computing loss due to tree or face mortality, a high interest rate would indicate less loss. In computing loss due to deferment of turpentining, however, the reverse is true. For example, the difference between the present worth of 12 years of turpentining and this value discounted for 2 years is 3.6 cents at 3 percent interest, and 5.2 cents at 5 percent.

It is recognized that in actual practice an interest rate above 3 percent might be desirable, depending upon a number of factors, including local business practice and salvage value in timber. The 3-percent rate, approximating the so-called "pure" or "risk-free" rate, was used because the principal purpose of the calculations was to indicate all the factors which should be considered in damage appraisal as well as the general size and range of naval stores losses resulting from fire.

A major point brought out by this study is the very great loss resulting from damage by a class 4 or severe crown fire, involving turpentining deferment for 2 years, face mortality, and tree mortality, as compared with that from damage by a class 3 or light crown fire, necessitating deferment of turpentining for 1 year only. Thus, assuming 50 turpentine trees per acre, the indicated loss caused by a class 4 fire is $23.37 per acre; by a class 3 fire, $1.08 per acre (table 10). The $22 difference explains why naval stores producers are greatly concerned over the danger of a serious crown fire. It also indicates why these men have been giving increasing attention to the possible advantages of controlled burning for fire protection.

As previously explained, controlled burning, if intelligently applied, reduces fuel hazards and causes little damage to gum yield. Under a program of such burning, no accidental fire would approach the destructiveness of a class 4 fire.

The $23 per acre loss from a class 4 fire is based on damage to naval stores values alone. To these must be added losses from major destruction of timber, in addition to naval stores, which yields lumber, pulpwood, and other wood products. It is clear therefore that a naval stores producer is justified in expending

TABLE 10. *Comparison of estimated typical losses per acre on turpentine trees resulting from class 3 and class 4 fires on a naval stores forest area*[1]

Class of fire and damage	Effect on turpentining	Trees affected	Total loss	Loss per acre
Class 3 fire:				
		Number	*Dollars*	*Dollars*
Defoliation	Deferment for 1 year	100,000	2,170	1.08
Class 4 fire:				
Tree mortality	Loss of 2 faces per tree	50,000	37,330	23.37
Face mortality	Loss of 1 face per tree	20,000	8,126	
Defoliation	Deferment for 2 years	30,000	1,287	
Total			46,743	

[1] Calculations based on a hypothetical burned area of 2,000 acres, 50 turpentine trees per acre, production of 50 units of naval stores per crop, and receipts of $60 per unit.

much thought and money to improve forest fire protection, either by controlled burning, better fire prevention and suppression, or a combination of these measures.

SUMMARY

The effects of three types of burning on the gum yield of longleaf and slash pines were studied at the Olustee Experimental Forest, Olustee, Fla., and in the vicinity. The treatments consisted of: (1) Removal of the dead and live vegetative cover of the soil by surface fire; and (2) defoliation of the trees by (a) heat-killing of the needles as in a hot ground fire, and (b) burning of the needles as in a mild crown fire; and (3) scorching the stems of the tree, as (a) in an ordinary face fire, and (b) in a very severe crown fire. Data on gum yield as affected by the first two types of burning were checked against comparable data from an area where an accidental fire had occurred.

Burning of the vegetative cover of the soil by surface fire increased the yield of longleaf pines about 4 percent during the succeeding year. With the insulating effect of plant cover removed, soil temperatures rise slightly higher on a freshly burned area than on one that has not recently been burned. The yield during the second year after the fire apparently was little affected. Evidence was presented which indicates that similar effects can be expected on slash pines.

For both species, heat treatment that killed needles decreased yield during the first succeeding year by as much as 19 percent, and flame treatment (as in a mild crown fire) by as much as 64 percent. The greater effect of the latter treatment is attributed to the injury to buds and twigs. Under both kinds of treatment, the decrease in yield depended upon the degree and season of defoliation. Twice as much reduction in yield was associated with complete as with two-thirds defoliation, and about 4 times as much with two-thirds as with one-third defoliation. Defoliation in late spring caused about twice as much reduction in yield as defoliation in early spring. All yields during the second year after the defoliation treatments were approximately normal. No tree mortality resulted from the treatments.

Stem scorching caused no serious reduction in yield except in the case of a particularly heavy crown fire. Such a fire, which

killed outright or caused subsequent death of 50 percent of the turpentine trees, injured the stems of 32 percent of the surviving trees to an extent that necessitated permanent abandonment of the existing faces.

Results of this study indicate that it is wise to defer turpentining for 1 year after a mild crown fire and for 2 years after a heavy crown fire.

With respect to financial investment and returns, the results indicate the following:

A surface fire that causes little or no heat defoliation of turpentine trees increases the value of the naval stores lease by about 0.25 cent per tree for the first year after the fire. On the other hand, a surface fire that causes marked heat defoliation, such as that which often results from the traditional—and misnamed—"light burning," decreases the lease value slightly. A severe crown fire, causing face and tree mortality and a 2-year deferment of turpentining, results in a loss that, on an area where the turpentine trees average 50 per acre, amounts to about $23 per acre. On such an area a light crown fire, causing defoliation and a 1-year deferment of turpentining, results in a loss of about $1 per acre.

LITERATURE CITED

(1) BAKER, H. L.
1929. FIRE IN THE TURPENTINE ORCHARD. Pine Inst. Amer. Pine Tree Chem. Indus. Yearbook 1929: 55-57.

(2) CARY, A.
1928. HOW THE YIELD OF GUM IS AFFECTED BY SCORCHING OF TREES. Naval Stores Rev. 37 (49): 26.

(3) DEMMON, E. L.
1935. THE SILVICULTURAL ASPECTS OF THE FOREST-FIRE PROBLEM IN THE LONGLEAF PINE REGION. Jour. Forestry 33: 323-331.

(4) DIXON, H. H.
1914. TRANSPIRATION AND THE ASCENT OF SAP IN PLANTS. 216 pp., illus. London.

(5) ELDREDGE, I. F.
1935. ADMINISTRATIVE PROBLEMS IN FIRE CONTROL IN THE LONGLEAF-SLASH PINE REGION OF THE SOUTH. Jour. Forestry 33: 342-346.

(6) GERRY, E.
1931. OLEORESIN PRODUCTION FROM LONGLEAF PINE DEFOLIATED BY FIRE. Jour. Agr. Res. 43: 827-836, illus.

(7) GREENE, S. W.
1935. RELATION BETWEEN WINTER GRASS FIRES AND CATTLE GRAZING IN THE LONGLEAF PINE BELT. Jour. Forestry 33: 338-341.

(8) HARPER, V. L., and WYMAN, L.
1936. VARIATIONS IN NAVAL-STORES YIELDS ASSOCIATED WITH WEATHER AND SPECIFIC DAYS BETWEEN CHIPPINGS. U. S. Dept. Agr. Tech. Bul. 510, 34 pp., illus.

(9) HEYWARD, F., and BARNETTE, R. M.
1934. EFFECT OF FREQUENT FIRES ON CHEMICAL COMPOSITION OF FOREST SOILS IN THE LONGLEAF PINE REGION. Fla. Agr. Expt. Sta. Bul. 265, 39 pp., illus.

(10) ——— and BARNETTE, R. M.
1936. FIELD CHARACTERISTICS AND PARTIAL CHEMICAL ANALYSES OF THE HUMUS LAYER OF LONGLEAF PINE FOREST SOILS. Fla. Agr. Expt. Sta. Bul. 302, 27 pp., illus.

(11) Kramer, P. J.
1942. species differences with respect to water absorption at low soil temperatures. Amer. Jour. Bot. 29: 828-831.

(12) MacKinney, A. L.
1934. some factors affecting the bark thickness of second-growth longleaf pine. Jour. Forestry 32: 470-471.

(13) Meyer, B. S., and Anderson, D. B.
1939. plant physiology. 696 pp., illus. New York.

(14) Stoddard, H. L.
1933. use of controlled fire in southeastern upland game management. Jour. Forestry 33: 346-351.

(15) U. S. Department of Agriculture.
1935. a naval stores handbook dealing with the production of pine gum or oleoresin. U. S. Dept. Agr. Mis. Pub. 209, 201 pp., illus.

(16) Wahlenberg, W. G.
1935. effect of fire and grazing on soil properties and the natural reproduction of longleaf pine. Jour. Forestry 33: 331-338.

(17) ———
1936. effect of annual burning on thickness of bark in second-growth longleaf pine stands at McNeill, Miss. Jour. Forestry 34: 79-81.

(18) ———, Greene, S. W., and Reed, H. R.
1939. effect of fire and cattle grazing on longleaf pine lands as studied at McNeill, Miss. U. S. Dept. Agr. Tech. Bul. 683, 52 pp., illus.

U. S. GOVERNMENT PRINTING OFFICE: 1944—600211

For sale by the Superintendent of Documents, Washington, D.C.